WOUNDS IN WAR

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THE MECHANISM OF THEIR PRODUCTION AND THEIR TREATMENT

BY

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PREFACE

PROBABLY no branch of surgery has undergone more important changes, in consequence of the teachings of Lister and of Pasteur, than that of gunshot wounds. As antiseptic methods have, in certain cases, rendered possible the performance of operations on regions of the body hitherto untouched by the civil surgeon, and as they have, in others, enabled him to avoid interference, and warranted him in substituting conservative treatment for the more radical measures of earlier times, so they have, in the treatment of the wounded in war, enabled the military surgeon to save lives and limbs, the latter of which, at all events, would, in the days of Larrey and Guthrie, have been sacrificed without hesitation.

At the end of the last century, during the Peninsular War, and even in the Crimea, a gunshot wound of a long bone, and more especially one implicating a large joint, was held to demand immediate amputation. But of late years the employment of antiseptics has so revolutionised the surgery of war that no general rule of this kind is admissible for a moment, and amputations for gunshots are only taken into consideration when the disorganisation of a limb is so extreme that but little of it remains to be preserved by conservative treatment, and when that little is more likely to prove an encumbrance than a help to its possessor if retained by the successful issue of the system applied. In pre-antiseptic days, hospital gangrene, septicæmia, and surgical infective disease generally were the causes of almost all the deaths which occurred in war hos-

pitals; in future these fatal scourges of the wounded in the field, which were remarkable for the manner in which their virulence and lethal influences increased as the duration of a campaign continued, may be expected to be only noticeable by their absence.

As the improvements which have taken place in modern surgery have necessitated changes in the methods of treatment of gunshot wounds, as of all others, so also the very conditions themselves of these injuries have changed. The projectiles which for the most part cause them, and the small-arms now in the hands of soldiers, are quite different from those formerly in use, and produce injuries, both of soft parts and of bone, quite unlike those seen in even the later campaigns. So much so that, even setting aside the many changes in surgical technique which have, within the last few years, so greatly modified treatment, it is very possible that the class of wound resulting from the hard-mantled bullet of small diameter now used requires a line of treatment different from that suitable for those resulting from the older and larger missiles. Thus for two reasons the surgical treatment of gunshot wounds in the wars of the future will vary greatly from what has obtained in the past. The science of surgery has itself altered, and the injuries to be treated will be modified by the changes which have been made in the weapons and projectiles employed.

To indicate the lines on which the modern treatment of wounds in war should be carried out in special injuries of particular parts of the body, and to point out what methods are calculated to bring about the best results in the preservation of lives and limbs in individual cases, have been the objects aimed at in the following pages.

On the Continent valuable works on the modern treatment of gunshot wounds have been published; but in this country the only book which has appeared since antiseptics have been used in warfare is the second edition of the late Sir Thomas Longmore's classical work on "Gunshot Injuries," of the excellence of which military surgeons of all countries are fully aware. It is a book of reference all

over the world, and its authority is quoted in almost every treatise that has been written on the subject since its first publication in 1877. But it deals with the treatment of gunshots in general terms, taking only a comprehensive view of the subject as a whole, and not entering into the particular lines of procedure which might be most advantageously carried out in special cases.

It has been my purpose in the present work to endeavour to suggest the appropriate methods of treatment to be pursued in wounds of almost every situation in the body, these necessarily depending upon and varying with the different degrees of damage found in each particular case; and to indicate when conservative measures may be adopted with a sufficient hope of success to warrant the possible extra risk to the patient; as well as to lay down rules, as far as rules on such matters are applicable, for the necessity of operative interference.

In pointing out the different means to be applied in the treatment of particular injuries, I have quoted the opinions of the highest authorities on military surgery, Sir Thomas Longmore, Sir William MacCormac, Delorme, Chauvel and Nimier, Esmarch, Langenbeck, and many others, and I have freely availed myself of that inexhaustible source of information on this subject, "The Surgical History of the War of the Rebellion" in the United States, by G. A. Otis, a work which must continue to be a record of labour and research which may never be surpassed. But, while giving the reader the benefit of the opinions of others, I have also stated the line of treatment which I should myself adopt.

Except in special cases where particular methods are indicated as the most suitable under the circumstances, operations, such as amputations, excisions, &c., are not described: these procedures are, for the most part, referred to in general terms only. To have done otherwise would have largely increased the size of the book, already perhaps too great, and these matters can be more effectively dealt with in systematic works on operative surgery.

My hope in writing the work has been that it may

prove of use to my brother officers in the three services in times of difficulty and doubt and under the trying circumstances of field surgery, as well as to those of my colleagues in civil practice who interest themselves in the subjects treated of. The notes of my lectures at the Army Medical School are its foundation. Its incompleteness I fully recognise, but if it fulfils the hope above expressed, it will have justified its existence and done as much as I expect of it.

W. F. S.

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WOUNDS IN WAR

CHAPTER I

INTRODUCTORY REMARKS—GUNSHOT WOUNDS IN GENERAL—PORTABLE FIRE-ARMS—THE MECHANICS OF PROJECTILES

EVEN in the very early days of fire-arms, when only smooth-bore muskets and artillery guns were in use, the large majority of wounds in war were those produced by projectiles of one kind or another. Compared with injuries of this class, wounds from side-arms—the bayonet, sword, lance, &c., were of rare occurrence. But since rifles have come into common use, and more specially in consequence of the vast improvements that have, in modern times, been made in these weapons, giving to them great increase of accuracy and enormous increase of range, the disproportion between the numbers injured in battle by fire-arms and by side-arms has become so great that the study of wounds in war may be said to resolve itself, almost exclusively, into one of gunshot wounds.

Bayonet and sword wounds, as well as those of all other kinds of side-arms, do of course occur; but their frequency is so insignificant, as compared with that of rifle projectiles, that they may almost be set aside. Field-guns and portable fire-arms have in recent years reached such a pitch of perfection, and are so destructive to fighting men, and at such long distances, that but little opportunity arises for injuries from other kinds of weapons to occur in warfare. The men of almost every branch of the service in

all armies are nowadays supplied with a fire-arm of one kind or another, rifle, carbine, or revolver. Thus the injuries which the military surgeon may expect to have to treat on active service may be considered almost altogether as those of gun and rifle projectiles.

Delorme[1] gives the proportion of wounds by side-arms occurring in the wars of the latter half of the present century as from 2 to 3 per cent. of all wounds; of all wounds treated during the war in America, only 0.37 per cent. were sabre and bayonet wounds.[2] MM. Chauvel and Nimier[3] put the percentage somewhat higher; but, at the lowest calculation, we may depend on at least 95 per cent. of the wounds in war being the results of rifle-bullets, or of shells or their fragments.

If, in former days, when combatants seldom opened any sustained fire on each other at over 100 yards' range, bayonet and sword wounds were infrequent, in modern times, when rifles are effective up to 3000 yards and more, they must be expected to be of still more rare occurrence. But little opportunity for such hand-to-hand fights as would render such injuries numerous, will arise, except in cavalry encounters, surprises, night attacks, and the assault of entrenched positions. Conclusive bayonet charges on a large scale seldom occurred at any time in history; in future the ordinary battle will, for the most part, be fought at such long ranges that they can hardly happen at all.

A glance at the statistics of the American War marks most forcibly the great preponderance of gunshot wounds over those produced by other weapons. Of over 246,000 wounded men in that war, only 922 received sword or bayonet wounds, or, as already mentioned, 0.37 per cent., and of these, Otis tells us that a "large proportion were inflicted in private quarrels or broils, or by sentinels in the discharge of their duty." Amongst the English army in the Crimea there was a total of 10,129 cases of wounds by weapons of war treated in the hospitals; of these, 158

[1] *Traité de Chirurgie de Guerre*, par E. Delorme, 1888.
[2] "Surgical History of the War of the Rebellion," Otis, vol. iii.
[3] *Traité de Chirurgie d'Armée*, par J. Chauvel et H. Nimier, 1890.

were cases of sword and bayonet wounds, or 1.5 per cent.[1] The French in the same war had 3.0 per cent. of similar injuries in a total of over 26,000 wounded;[2] and the Germans in 1870–71, out of 54,268 cases, show a percentage of 1.4 for sword and bayonet wounds.[3]

Moreover, wounds by side-arms do not bear that special interest for military surgeons that gunshot injuries always carry with them. They are similar to those met with in civil practice; whereas gunshot wounds are comparatively rare in civil hospitals, and even then they are usually produced by fire-arms having very different characteristics from those of the military weapon, and causing very different wounds. Spear and sword wounds are, probably, seen more often in our own army than in that of any other country. The campaigns in which the English army has been engaged since that of the Crimea have all been against savage or half-civilised enemies, and wounds of this class are more common in these cases. In South Africa, in the Soudan, and on the Indian frontier, spear and sword wounds have been comparatively common. The Asiatic fanatic attacks his white enemy, caring nothing for the result to himself, and thus oftener gets within striking distance, and wounds of the class under consideration are more frequently produced.

Wounds caused by the European sword or sabre differ greatly from those of the Indian weapon: they are as much contusions as they are incised wounds, the edges of European swords being by no means sharp. The Asiatic sword is heavy, much curved, and possesses a cutting edge of extreme keenness; the injuries resulting from it are clean-cut incisions, presenting no appearance of contusion, and are frequently of great extent both as regards depth and length. Some specimens[4] of skull injury in the Surgical Museum at the Army Medical School, Netley, show this

[1] Matthew, "Medical and Surgical History of the British Army in the Crimea."

[2] Chenu, *Rapport au Conseil de Santé des Armées, &c., pendant la Campagne d'Orient en* 1854–55–56.

[3] Fischer, "Statistics of the War of 1870-71."

[4] Nos. 2907–2909 and 2910 in Museum Catalogue, Netley.

characteristic of sword wounds resulting from the Indian weapon in a very marked degree: they are the skulls of some men who were killed at Peshawar by Afghans during a night raid, and in them are seen clean incisions of the bone, with no fissuring, evidently made by the heavy and extremely sharp Afghan knife (fig. 1), so called, but which is in reality a sword to all intents and purposes. An excellent description, with plates, of the injuries produced by this weapon in the Waziristan expedition of 1894, by

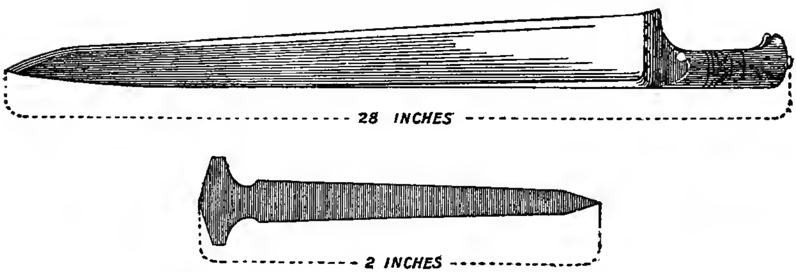


FIG. 1.—Afghan Knife.

Surgeon-Captain Bruce Seton, I.M.S., will be found in the *British Medical Journal* for January 1895.

Bayonet, lance, and spear wounds, as well as those from thrusts of the straighter kinds of swords, come, of course, under the head of punctured wounds, and the importance of this class of injury depends on the depth to which they reach, as well as on the tissues through which they pass. Hitherto they have been prone to prolonged suppuration, and it remains to be seen how effectually or otherwise the modern treatment by dry and antiseptic dressings will prevent this complication. With early and thorough irrigation to the bottom of the track, they should, in future, run a more satisfactory course. The more detailed treatment of wounds by side-arms will be referred to later on.

Gunshot Wounds.—The class of wounds in war which principally occupies the military surgeon on active service, and which therefore has for him a special interest, is that of gunshot wounds: they comprise over 95 per cent. of the

cases of injury he treats on a campaign, and they constitute, in these days, a special branch in surgery. Dupuytren and John Hunter both referred to gunshot wounds as a "specialism" in surgery. These two great surgeons considered that there was much to be learned regarding gunshot wounds; that they possessed peculiarities with which the civil surgeon was not likely to be familiar, and since the times of Dupuytren and John Hunter these peculiarities have become much more marked. The great energy developed in the modern bullet, the hardness of its outer covering, the high rate of rotatory motion imparted to it, and especially its shape and weight, are accountable for the peculiarities of the wounds it produces.

Again, the very surroundings of the soldier wounded in battle entail peculiarities in his treatment, even as a surgical case, for they are very different from those of a man wounded in civil life, even were the injuries similar. Conservative surgery has a wider field and a more hopeful outlook in the latter than in the former case. The surgeon with all the resources and appliances and the restful circumstances of a civil hospital at his command, may often successfully endeavour to save a limb or a joint where his military colleague knows that he will be well satisfied if he saves his patient's life: the absolute necessity, owing to the military exigencies of a campaign, of removing wounded men from the front towards the base of operations, with which no merely humanitarian considerations can be allowed to interfere, is usually the cause of the differences in treatment between civil and military practice, as well as of the difficulties inherent in the latter.

Ballingall[1] defines military surgery as "the judicious application of all the subdivisions of the healing art to those varied circumstances in which soldiers are placed both in health and in sickness." To the question, "Is the arm of the hero of the age, or are the arms of his heroic followers, of a different anatomical mould from the limbs of him who guides the plough?" he replies, "No; but the arm of his country's champion is subject to accidents of a

[1] "Outlines of Military Surgery," Sir G. Ballingall, 1834.

kind little known to the ploughman or the labourer, and has to be treated under circumstances totally unknown to the tranquillity of rural life." M. Delorme, the professor at the Val de Grace, writes:[1] "The present position of military surgery is the work of ages. We have seen that, from the time of Paré up to our own day, the tendency of the best minds has been directed to keeping its practice apart from that of general surgery. Military surgery, in its early days, had begun by being a temporary employment for the civil practitioner. Whatever we may think or say, military surgery will always be a surgical speciality. If it derives from the common origin of surgery a portion of its doctrines and its teaching, it also keeps its own peculiarities. Its pathology depends upon a variety of injuries of a special nature, always varying with the armament and with the military operations; its therapeutics are subject to peculiar influences dependent on conditions not analogous to those of civil practice. Let us add, in fine, that of all surgical specialisms it is the one which preserves the loosest bonds with general surgery, and that the dangers of its practice on the field of battle make it the expression of the most noble, the most elevating of all forms of human assistance."

Sir Thomas Longmore, in the preface to his first edition, very forcibly points out the difficulties with which the subject of gunshot wounds in war are surrounded, when he says that "it is only by previous careful study, by scientific acquaintance not only with the injuries themselves, but also with the instruments and forces by which they are produced, and on which their special features depend, and by a knowledge of the experience which has been gained by successive practical observers, that the nature and characters of gunshot injuries can be properly understood, or their appropriate treatment determined."

Every surgeon must be understood to be ready, at a moment's notice, to act in the best interest of his patient; to be ready to afford the proper assistance in a moment of emergency. But for the surgeon following his profession

[1] *Op. cit.*

on the field of battle, how much more than for his civil colleague must he be prepared to act on his own unaided judgment, and at short notice. Almost immediately an action begins, in the field hospitals, which until then were empty, all is changed in a moment to a condition of overcrowding with crushed and mangled men, and far more work than the surgeons available can readily perform. "The injuries occur so numerously on fields of battle, and in such rapid sequence—to a vast extent, indeed, it may be said, simultaneously—that, to afford efficient aid, the surgeon's decision and action must be ready on the moment." "Lives depend on assistance being given without hesitation and on the instant." "To be of real service, not only must the urgent demands for surgical aid be met at once; they must also be responded to suitably, according to the special exigencies of each particular case. Self-reliance gained from knowledge, the wit to turn everything at hand to account, and previously acquired manual dexterity will alone enable the army surgeon to fulfil his duties on such occasions with benefit to others and with satisfaction to himself." [1]

In modern days the efficient army medical officer must, in time of peace, be a good general surgeon and physician, and he is responsible for the duties in connection with the command and discipline of men and the internal economy of corps; he must therefore be acquainted with military law and the regulations affecting his own and other branches of the service. In time of war he must be a specialist in the diagnosis and treatment of gunshot wounds. To prepare himself for the latter he must study the experience of others in a like field, detailed in the records which they have left behind them, for he will probably have had but little practical experience himself in this matter, which, after all, is his real *raison d'être*, until he finds himself face to face with the necessities of the case in a field hospital. Happy will it be for him then if he has made good use of his time and opportunities, if he finds himself rapid in diagnosis and expert in operative procedure, for under no other circumstances are quickness of judgment and opera-

[1] Longmore.

tive dexterity of so much avail to the surgeon and to his patients as in the hospitals on the field of battle.

Portable Fire-arms.—In order that the military surgeon should be able to form clear and correct ideas on the subject of gunshot wounds, their diagnosis and their treatment, it is necessary that he should thoroughly understand the qualities and characteristics of the weapons and missiles which produce them. He must possess the same kind of knowledge of fire-arms and of projectiles as that required by the musketry instructor. He must know the principles on which rifles and other portable fire-arms are constructed; the weights, forms, and velocities of bullets, as well as the forces which act upon them, and the natural laws which govern the flight of projectiles; for on these depend the peculiarities of the injuries he will have to treat in war. Both Longmore and Delorme insist upon this. The former writes: "Whatever increases in a marked degree the velocity of movement, force, and range of projectiles, whether it be alterations in the projectiles themselves, or in the fire-arms from which they are discharged, changes proportionally the features of the injuries inflicted by them, and, within certain limits, the treatment necessary for their cure"; while the latter points out that "the laws of ballistics are a difficult and thankless study, but a knowledge of them is of inestimable value to the army surgeon." I shall therefore devote some of the following pages to a description of the fire-arms formerly and at present in use in some of the European armies, and to the theories and ascertained facts in connection with them, and of the bullets discharged by them, their forms, weights, velocities, &c., and to an explanation of the laws which govern the flight of projectiles generally. To know the most we can of the injuries we have to treat, it must be of service to us to be acquainted with the instruments which cause them, and the laws and conditions which modify their effects. It will therefore be necessary to describe, somewhat in detail, the fire-arms which have been in use in armies, and, more especially, the small-bore rifles with which the soldiers of all European armies are now armed.

Fire-arms first came into use in warfare in the beginning of the fourteenth century, the "hand-gun" coming into practical use in 1446. This weapon was of very rude construction, being simply a metal tube with a touch-hole; this tube was attached to a wooden staff which passed under the soldier's armpit. The "hand-gun" underwent many modifications for its improvement, and in the sixteenth century a musket was invented by the Spaniards, with a view to a fire-arm which would throw a larger and heavier ball, one about ten to the pound. This was at first the matchlock or firelock, and later on the snaphaunce. This latter weapon, which was fired by means of a flint, suggested, no doubt, the more modern flintlock.

The English flintlock musket in use at the beginning of this century, and its ammunition, were as follows:—

Weight of musket with bayonet .	11 lbs. 4 oz.
" bayonet . . .	1 lb. 2 oz.
Length of barrel	3 ft. 3 ins.
Diameter of bore	.753 ins.
Bullets, spherical, pure lead . .	14½ to lb.
Charge of powder	6 drs.
With 3 flints to every 60 rounds.	

The action of the flintlock was always uncertain; frequently the priming powder became damp and failed to

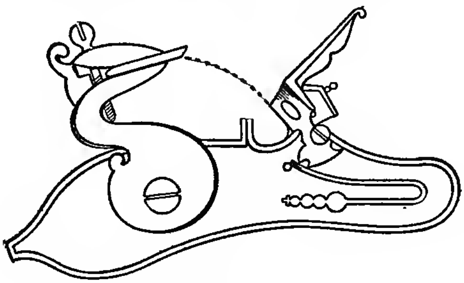


FIG. 2.—Flintlock of "Brown Bess."

ignite. To overcome this difficulty, the Rev. Mr. Forsyth, in 1807, invented and patented a fulminating powder, consisting of chlorate of potash, sulphur, and charcoal, but which was afterwards improved. An exhaustive trial of

the percussion musket, made in 1834 at Woolwich, conclusively proved the superiority of the percussion principle, and in 1839 the army flintlock, then in use, was altered to suit the new method. The percussion musket of 1842 was in all essentials similar to the older flintlock, except that the lock was changed and the powder charge reduced to 4½ drs. This continued to be the service weapon of our army until it was superseded partially in 1851 by the Minié rifle, and altogether by the Enfield rifle in 1855.

Rifles.—All the rifled small-arms now in use have developed by a process of evolution from the Minié rifle, invented by Captain Minié, an instructor at the school at Vincennes, about 1847—although what Captain Minié really invented was not a new rifle, but rather a new bullet, having an iron cup in the base which undergoes expansion into the grooves of the barrel from the pressure of the powder gas, thus ensuring the rotatory motion of the bullet. A system of grooving musket-barrels had been invented about 1520, but rifles were not used in warfare until about the middle of the seventeenth century; and although in the English army, the old 95th Regiment, now the Rifle Brigade, was in 1800 armed with Baker's rifle, firing a round bullet, yet this class of fire-arm was held in but little estimation until long after that date.

The great difficulty in the use of the muzzle-loading rifle has always been experienced in loading it; the bullet of a muzzle-loading rifle must be tight enough in the barrel to take the grooving, and yet it must be small enough to admit of easy loading from the muzzle. Even if these two opposed conditions can be achieved, it becomes most difficult, almost impossible, to load the weapon after any long-continued firing, on account of the fouling of the barrel. Various devices[1] tending to overcome this difficulty, and many new kinds of rifles, were invented and tried, but no real advances towards the desired end were made until M. Delvigne, a French infantry officer in 1841, announced the fact that elongated bullets having a hollow in the base had their bases expanded into the grooves by the pressure of

[1] See "Text-Book on Military Small-Arms and Ammunition," 1894.

the powder gas. This discovery practically removed all difficulty in the use of muzzle-loading rifles. Bullets of this pattern could be used of such diameter that they easily passed down the barrel, while the expansion of the base ensured their taking the grooving.

In 1847, Captain Minié suggested the placing of an iron cup (fig. 3) in the hollow in the base of the bullet, as he found that this rendered the expansion more certain and more complete. This invention constituted a definite solution of the principle of expansion. Rifled muskets firing Minié bullets (fig. 4) were usually designated "Minié rifles," although the weapons were really of the old form, and Captain Minié had not invented the rifle, but only the projectile used with it. The Minié rifle was as follows:—

Weight with bayonet . . .	10 lbs. 8¾ oz.
Diameter of bore	.702 in.
Grooves	4.
Twist	1 turn in 78 ins.
Diameter of bullet . . .	.690 in.
Weight "	680 grains.
Charge of powder	2½ drs.
Sighted from 100 to 1000 yards.	

A portion of the English army which landed in the Crimea in 1854 was armed with Minié rifles, and the vast

FIG. 3.—Metal Cup in Base of Minié Bullet.

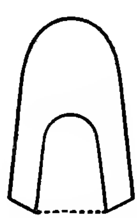


FIG. 4.—Minié Bullet.

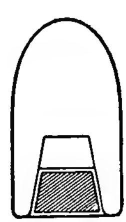


FIG. 5.—Enfield Bullet.

superiority of the rifled weapon over the old smooth-bore musket was so evident at the battles of Alma and Inkerman, that the whole army in the Crimea was supplied with a newer and still more effective fire-arm in 1855 while the

war was being carried on. This was the Enfield 3-grooved rifle, "pattern 1853"; the weight, &c., were as follows:—

Weight with bayonet	9 lbs. 3 oz.
Calibre	.577 in.
Grooves	3, 1 turn in 78 ins.
Charge of powder	2½ drs.
Diameter of bullet	.568 in.
Weight "	530 grains.

The bullet (fig. 5) was cylindro-conoidal in shape, having a large hollow in the base; at first no iron cup was used with it, but afterwards this was supplied, and, later still, a boxwood plug was substituted for it.

Many changes and improvements were made in the Enfield rifle, as regards sighting, calibre, form of bullet, &c., &c., but it continued to be the weapon of the English army until 1871, when it was replaced by a breech-loader.

The Prussians were the first to use a breech-loader in war, and the great advantages of this class of fire-arm were so marked in the Danish War of 1864, and against the Austrians in 1866, the Prussians using breech-loading needle-guns on both occasions, that all the governments of Europe set about providing their soldiers with rifles on similar principles. Our own Enfield rifle was converted, on the plan of a Mr. Snider, into a serviceable breech-loader, using a metallic cartridge invented by Colonel Boxer, R.A., Superintendent of the Laboratory at the Royal Arsenal, Woolwich. No changes were made in the bullet or in the barrel of the rifle, and the weapon was known as the "Snider-converted-Enfield rifle."

In 1866 a special Committee of Officers was appointed by the War Office to consider and report on newly invented breech-loaders with a view to the selection of a completely new breech-loading rifle. As a result, in February 1869, after careful trial of a large number of experimental weapons, with various combinations of barrel and breech action, the committee reported in favour of a rifle having a combination of the block-action breech mechanism submitted by Mr. Martini, made and modified at Enfield, with Mr.

Henry's barrel, having a calibre of .45 inch, and 7 grooves with a uniform right-handed twist of 1 turn in 22 inches, the arm to be called the "Martini-Henry." This rifle was adopted in April 1871, and was in the hands of English soldiers until July 1888, when 350 Mark I. Lee-Metford magazine rifles were issued for trial to the troops, and were satisfactorily reported on as regards the efficiency of the weapons. Some minor improvements were subsequently made in the Mark I. pattern, and the rifle was finally adopted in December 1888. The magazine of Mark I. held 8 cartridges, but the Small-Arm Committee recommended one holding 10 cartridges, and as a result the Lee-Metford magazine rifle, Mark II., was formally approved, and a pattern sealed in December 1891. This is the weapon now in use in the British army.

The term "small-bore," as referred to fire-arms, is a relative one; the Snider rifle was a small-bore compared to previous weapons, the Martini-Henry as compared to the Snider. The Lee-Metford is the present English "small-bore," which may be defined in modern times as any rifle of less than .350 in. in calibre. It fires an elongated bullet (fig. 6) composed of a core of lead hardened with antimony incased in an envelope of cupro-nickel alloy, 1.25 in. in length, of 0.311 ins. diameter, and having an ogival head of two diameters, slightly flattened at the extreme point. It has been found necessary to use composite bullets with all modern rifles, because the muzzle velocity of the missiles discharged by them is so high, and the twist of the rifling so rapid (1 in 10 ins.), that were pure, or even hardened, lead used, the bullets would be driven through the barrel without taking the grooves, so much of the metal being torn off as would permit of this, the result being that a few rounds would render the rifle unserviceable from "leading" of the barrel, and the bullet would not receive the necessary rotatory

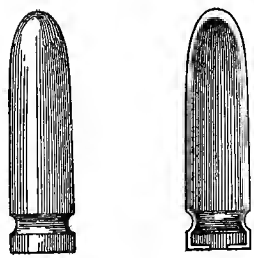


FIG. 6.—Lee-Metford Bullet, and Section of same.

motion on its long axis upon which the superiority of rifles over smooth-bores mostly depends. To obviate this tendency to stripping of the bullet, and to ensure its engaging the grooves, and so obtaining the requisite "spin," the envelope of harder metal has been given to the bullet.

The change from smooth-bored to rifled weapons has greatly increased the accuracy of aim and the extent of range, while the substitution of breech-loading for muzzle-loading rifles has increased the capability of fire tenfold, and this latter has been still further augmented by the new magazine arrangement.

The Mechanics of Projectiles.—To understand correctly the movements of bullets, it is necessary to refer to some elementary laws of mechanics, a knowledge of which is absolutely essential for the army surgeon, if he wishes to understand the injuries he will have to deal with, both with regard to prognosis and treatment. Longmore's opinion on this matter I have already quoted. Delorme, on the same subject, writes: "The calibres of the arms; the weights of their projectiles, their diameters; their 'initial velocities,' and their 'remaining velocities' at the different distances, ought to be equally well known by the military surgeon as by the combatants. Without this knowledge the army surgeon is deficient of the elements necessary for appreciating, from the commencement of the war, the characters and the gravity of the wounds he will have to treat, and for determining, with full knowledge of the causes, the probable rules for his interference." In order, therefore, to clearly understand the ballistics of projectiles, it is necessary to inquire into the mechanics of the subject, as regards the motion, energy, velocity, &c., &c., of moving bodies.

Motion.—A body is said to possess "motion" when it changes its position in space with regard to other bodies; in a word, the motion of a body is its change of position.

Velocity.—The velocity of a body is its *rate* of motion, or its rate of change of position. In order to measure or estimate the amount of anything, we require standards cr

units. The units used in this country for measuring the velocity of projectiles are feet and seconds; thus we talk of the velocity of a bullet being 1850 foot-seconds, meaning thereby that a bullet moving at that rate would pass over 1850 feet in one second; and this method of estimating velocity is called the "foot-second" system. It gives the number of units of length passed over in a unit of time.

"Initial" and "Remaining Velocity."—Two phases, as it were, of velocity are referred to with regard to projectiles, "initial velocity" and "remaining velocity." The "initial velocity" of a bullet is its velocity at the instant it leaves the muzzle of the gun; and "remaining velocity" is the amount of velocity still remaining in it at any given point in its flight: "remaining velocity" varies, of course, inversely as the distance from the firing-place.

Energy. — All moving bodies possess energy; and energy in mechanics may be defined to be the power of doing work or of overcoming resistance. The amount of energy in a moving body depends on its mass and on its velocity; it is, in fact, represented by the product of its mass into the square of its velocity. The formula, then, for the energy of a projectile is seen to be represented by MV^2, where M is the mass and V the velocity. Energy at rest is called "potential energy"—an energy which is not doing work, but which is capable of doing work on being liberated. Energy at work is called "kinetic or motive energy," and means the same thing as the vis viva of a moving body. The expression, then, for the vis viva or mechanical power of a projectile is MV^2, and the actual "work done" by a projectile in penetration and coming to a state of rest is half the vis viva, or $\frac{MV^2}{2}$, because at the beginning of penetration the capability of doing work is MV^2, and at the end of penetration it is nil, all the energy having been expended in penetration and coming to a standstill; the mean of the expressions MV^2 and o is $\frac{MV^2}{2}$, and must represent the actual *work* done. This expression is called the "equation of work," and will, if necessary, be

found more fully explained in any elementary work on Energy and Motion.

The work which a projectile is intended to do is to penetrate animal tissues and to break bones, and depends on the energy developed in it, as represented by the formula MV^2. It follows, therefore, that the destructive effects of a bullet depend much more on its velocity than on its mass or weight. The mass of a rifle-bullet is small; but when the small figure representing its mass comes to be multiplied by the *square* of such high velocities as bullets possess, and nowadays retain over long ranges, it will easily be understood that the energy developed in them is very great, and their destructive effects great in proportion.

Again, since the formula MV^2 represents the energy of a projectile, it follows that increase of velocity has much greater effect in increasing its power of causing injury than would increase of its weight. Doubling the mass of a bullet doubles its energy, but doubling its velocity increases its energy fourfold.

Motions of a Bullet.—A projectile from a gun or rifle, in its flight through the air, has two motions, one of translation and one of rotation, and is acted on by three forces—(1) the pressure of the powder gas urging it forward, (2) the resistance of the air retarding and gradually slowing its onward movement, and (3) the force of gravity bringing it to the ground. In vacuo, everything in nature falls towards the earth at the same rate, irrespective of its weight or bulk. Gravity is an accelerating force; the longer a body is acted on by gravity the faster it travels, the space through which it falls increasing directly as the square of the time through which the force acts. It varies slightly with the latitude of the place. In the latitude of London, a body falling in vacuo travels through 16 feet (omitting fractions) in the first second of time, and, starting from a state of rest, has, at the *end* of the first second, a velocity of 32 feet per second. At the end of the second second it will have fallen 64 feet (16 feet $\times$ 4, the time squared), and 144 feet at the end of the third second, *i.e.*

16 feet multiplied by 9, the square of the time, 3 seconds. Thus it is apparent that the longer gravity acts on a falling body, the greater is its effect, and the faster will be the descent.

If, then, we disregard the retarding force of the resistance of the air, if, in fact, we supppose a bullet to be discharged in vacuo, we know that, owing to the impressed force of the powder gas, it would travel forward at a *uniform velocity*, passing through equal distances in equal times, and, in obedience to the laws of gravity, falling towards the earth 16 feet in one second, 64 feet in two seconds, and so on, describing the curve called a parabola. Even in vacuo, therefore, the line of flight of a bullet would be a curved line, owing to the effect of gravity alone. But, under natural conditions, the resistance of the atmosphere so modifies the flight of a bullet that it does not travel forward at a uniform velocity, but that the distances traversed in equal times gradually become less and less. The trajectory, therefore, of a projectile is not in the form of a true parabola; the outer section of it is much more curved, much nearer the perpendicular, than the inner one, and this is due to the combination of the two conditions just referred to, both tending in the same direction—viz., the resistance of the air gradually diminishing its onward movement, and the accelerating force of gravity rapidly increasing its velocity of movement towards the earth. It is owing to the force of gravity that the trajectory of a projectile is always in a curved line, the curvature being increased by the resistance of the air as the onward velocity diminishes; and it is in consequence of the *acceleration* of the force of gravity increasing the velocity of the bullet towards the earth, and the resistance of the air *decreasing* its velocity forwards, that elevation must be given to rifles in an *increasing ratio* according to the distance of the object aimed at. Twice the elevation suitable for 500 yards will not carry the bullet to 1000 yards; the angle of elevation must be three or four times that necessary for the shorter distance. If gravity alone acted, elevation would be necessary; but the combined

effects of gravity and air resistance necessitate elevation in an increasing ratio.

A bullet discharged in vacuo would travel forward at a uniform velocity, doing equal distances in equal times, say from A to B, B to C, and C to D (fig. 7) in each second of time, and falling towards the earth 16 feet in one second, 64 feet in two seconds, 144 feet in three seconds, and so on, under the influence of gravity, the trajectory being in the form of a true parabola. Were it not for the effect of the force of gravity, the bullet would, at the end of the first, second, and third seconds, be at B, C, and D respectively (fig. 7); but, in fact, gravity would have drawn it to E, F, and G. The fall of a bullet towards the earth is quite independent of the quantity of powder it is discharged by, and of the velocity it is travelling at. A bullet discharged from a fire-arm placed parallel with the ground, and 16 feet above it, will reach the earth in one second, no matter what its velocity may be, and in two seconds if 64 feet above it. This is absolutely true only for bullets in vacuo, setting aside the resistance of the air; but for those discharged under natural conditions it is true that bullets of the same bulk and density will reach the ground at the same instant, if fired from the same height horizontally, or at the same angle of elevation, irrespective of their velocities. The velocity of the motion of translation of a projectile has no effect on the velocity of its fall towards the earth under the influence of gravity.

Effect of the Resistance of the Air on the Trajectory.—Taking now the resistance of the air into consideration: on account of this resistance, the bullet does not travel forward at a uniform velocity, but at a steadily diminishing one, the spaces traversed in equal times steadily becoming less and less. Thus the bullet, instead of arriving at B, C, and D (fig. 7) in the first, second, and third seconds respectively, will only have traversed the horizontal spaces A*b*, *bc*, and *cd* (fig. 7), while the force of gravity will have drawn it to *e*, *f*, and *g*. It is therefore apparent that, owing to the combined effects of the accelerating force of gravity and of the air resistance, the outer portion

of the trajectory of a projectile is more curved, and more nearly approaches the perpendicular, than the inner portion, and that elevation in an *increasing* ratio must be given to fire-arms, in order to carry their projectiles over the range as the latter becomes more extended.

The Motion of Rotation.—The second motion of a projectile which has to be taken into account is that of rotation. Bullets, whether discharged from smooth-bores or from rifles, all have communicated to them a rotatory motion: in the former case, on an axis the direction of which

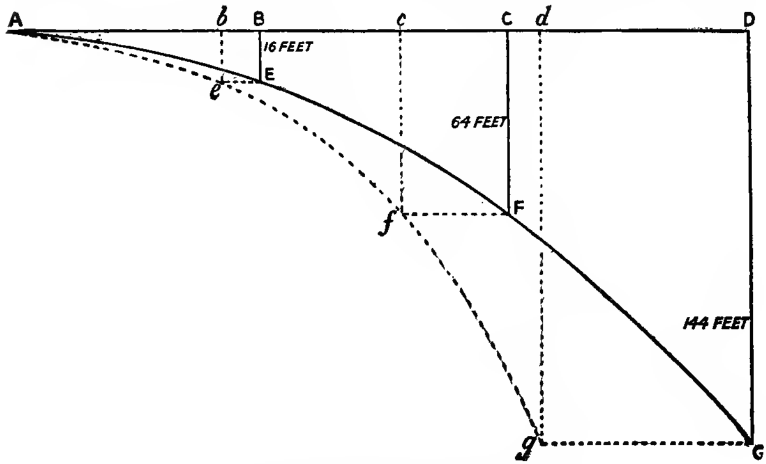


FIG. 7.—Trajectories in Vacuo and in Air.

is determined by that point on the inner surface of the barrel with which they were last in contact; and, in the case of rifles, on their long axis, in obedience to the twist of the grooves. The object attained by communicating a spin, or rotatory motion, to a projectile, is to keep its sharp end forwards, and the result of this is great increase of ranging power and of accuracy of aim. A cylindro-conoidal bullet projected from a smooth-bore musket would rotate on its shorter axis, and at even so short a range as 9 yards it would strike a target in its length. This is impossible when a rotatory motion on its longer axis is imparted to it by making it follow a definite twist of groove in a rifle-barrel.

The spin of a rifle-bullet is more rapid as the twists of the rifling are shorter and the velocity of translation greater. In the Minié rifle the length of the twist was said to be 78 inches, meaning that the grooves made one complete turn in 78 inches of the barrel; in the Martini-Henry it is 1 in 22 inches, and in the Lee-Metford 1 in 10 inches. The twist of rifling may also be expressed "in calibres"—one complete turn in so many lengths of the barrel measured in calibres; and this is really the more accurate method. The proper rate of twist for any given rifle can be determined theoretically, but practically this is always arrived at by experiment. The greater the length of a bullet the greater must be its velocity of rotation, and therefore the shorter must be the spiral of the rifling in the barrel to obtain the greatest accuracy of shooting. The velocity of rotation depends on the muzzle velocity of the bullet and on the rate of twist of the rifling; as the velocity of bullets has been increased, so it has been found necessary to make the twist of the rifling more rapid.

The velocity of the motion of translation of a bullet varies with the distance from the firing-point, chiefly owing to the resistance of the air: the velocity of rotation follows the accelerations and retardations of the former, and changes with it according to the distance. It therefore follows that the translation and rotation movements cease together when the former ceases by expenditure of energy. But when the motion of translation is suddenly and completely interrupted by contact with an obstacle, then the motion of rotation continues until its energy is expended.

Air Resistance.—The great obstacle to obtaining extreme ranging power in rifles is the resistance offered by the air to their projectiles; and on its account great attention has been paid and every effort made to discover the exact form of bullet which is least affected by it. Air resistance depends to a certain extent on the density of the atmosphere, but more especially on (1) the extent of surface the bullet presents to the air, on (2) the velocity of the bullet, on (3) its shape, and on (4) its "sectional density."

The denser the atmosphere is, the greater will be the difficulty with which its particles become displaced; and the greater the sectional area of the bullet, the greater is the resistance of the air, which varies directly as the square of the diameter of the projectile.

The Effect of Velocity on Resistance.—No unvarying law has been discovered which shows how air resistance is affected by velocity. It does not change regularly as the velocity changes, and M. Hélie, in France, and Rev. F. Bashforth, in England, arrived independently at similar results—viz., that resistance varies directly as (about) the square of the velocity at low and high velocities, and as (about) the cube and sixth power of the velocity at medium rates.

The Shape of the Bullet Head and Air Resistance.—The shape of the forward end of the bullet has considerable influence on the effect of resistance. Mr. Bashforth experimented with bullets having different forms of heads, and found the flat head, as might be expected, offered the greatest resistance to the air, and that the ogival head of two diameters[1] offered the least. Putting out of consideration the flat-headed projectile, which is known to encounter about twice the resistance offered by the air to the ogival head of two diameters, if the resistance of the air to the hemispherical head be represented by units, the resistance to the others of the same diameter, but with differently shaped heads, will be as follows:—

1.	Hemispherical head—air resistance . .	1.
2.	Hemispheroidal " " . . .	0.78.
3.	Ogival head of 1 diam. of base—air resistance	0.83.
4.	" 2 " " "	0.78.

A new form of bullet has lately (1893) been experimented on with regard to air resistance, and is referred to in the *Journal of the United Service Institution* for August, 1893. The Journal quotes the "*Revue du Cercle Militaire*,"

[1] The expression "ogival head of one or two diameters" means that the head of the bullet is formed of arcs of circles the radius of which is equal to one or two diameters of the base of the bullet.

No. 30, the account of the Krnka-Hebler bullet. This bullet is tubular, and conical at both ends. The width of the central tube is $\frac{2}{5}$ of the diameter. Fired from the German 7.06 mm. rifle, the air resistance was found to be represented by .12 as compared to the numbers given above, and the trajectory was much flatter than that of the ordinary bullet, the "dangerous zone" of the latter being, at 1000 m. range, 42 m., while that of the tubular bullet was 400 m.; but this form of bullet has not as yet been adopted with any military arm.

From this it will be seen that the hemispheroidal head and the ogival head of two diameters encounter about the

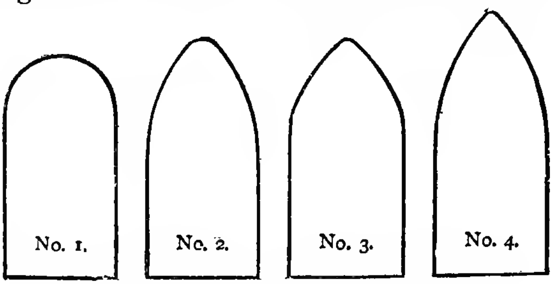


FIG. 8.—Different shapes of bullet heads.

same resistance, but at the higher rates of velocity the ogival head of two diamèters has greatly the advantage. More or less sharpness at the extreme point of the projectile was found not to affect the facility with which it displaces the particles of air, while its shape at the junction of the head with the cylindrical portion, or body, of the projectile, has a marked effect in this connection; the slope at this part should be as gentle as possible. It is, perhaps, a curious fact that the shape of the hinder end of a bullet also affects the facility with which it overcomes air resistance. To afford some idea of the power of air resistance, I may mention that wind blowing a gale has only a velocity of about 60 miles an hour, whereas a bullet travelling at as low a rate as 1300 feet per second has a velocity of over 886 miles an hour: or to put it in another way—in the gale of 14th October 1881 the greatest wind pressure observed at the Greenwich Observatory was 53 lbs. on the

square foot, due to a velocity of wind of about 61 miles an hour, or 0.368 lb. on the square inch and a velocity of 90 feet per second; but rifle projectiles frequently attain a velocity of 2200 f.s., equivalent to a pressure of 28 lbs. on the square inch, or about 76 times the wind pressure noted in the gale above referred to.

The facility with which a projectile overcomes the resistance of the air depends, then, to a large extent, on its shape. It depends also on other things. Of two bullets of equal weights and diameters, the longer will have the more extended ranging power. But of all the qualities of a projectile in this connection, most depends on what is called its "sectional density." It has already been stated that the effect of air resistance on a bullet varies directly as the square of its greatest diameter, and inversely as its weight. The term "sectional density" is used to express the proportion between the area of the cross-section of a bullet and its weight. This ratio may be expressed in the following formula—sectional density $= \frac{\text{weight of bullet}}{\text{area of cross-section.}}$ The sectional density of a projectile is, therefore, high as its weight is great and the area of its cross-section small. The retardation of a projectile is proportional to

$$\frac{\text{Area of cross-section}}{\text{Weight of bullet ;}}$$

while its ranging power (which depends on its capability of overcoming air resistance) is proportional to

$$\frac{\text{Weight of bullet}}{\text{Area of cross-section.}}$$

Trajectories.—The trajectory of a projectile is the curved line it describes in its flight from the muzzle of the fire-arm to the first point of impact. It has already been explained why this line is in the form of a curve, and why its outer sections are more curved than its inner ones. Soon after a bullet leaves the muzzle of a rifle, in consequence of the curved form of its line of flight, it rises to a height greater than that of a man, who would not, therefore, be wounded by it; it continues to rise until it

reaches its highest or "culminating point," when it begins to descend. A bullet is only dangerous to men or animals when in its course it has come sufficiently close to the ground to strike them, that is when it has reached the point of "first catch" on its trajectory, and from thence onwards. The point of "first catch" is for cavalry about 8½ feet from the ground, and for infantry about 6 feet. The "dangerous zone" of a projectile is from the "first catch" to the end of its flight, because only along that part of its course is it dangerous to men or animals.

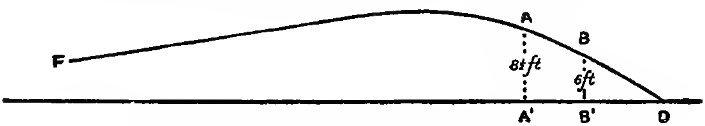


FIG. 9.—Trajectory, showing dangerous zones.

A. First catch for cavalry. B. First catch for infantry. D = end of range. F = firing-place. A = 8½ feet above ground. B = 6 feet above ground. A'D = dangerous zone for cavalry. B'D = dangerous zone for infantry.

In the above figure the height of the trajectory is, of course, much exaggerated as compared with the horizontal distance between F and D, but it explains the meaning of the text.

From what has been already said, it will be apparent that the flatter the trajectory of a bullet is, the more extended will be its dangerous zone, and the more efficacious the rifle. If it were possible to cause a bullet to travel parallel to the ground, to give it, in fact, a perfectly flat trajectory, the dangerous zone would extend from the muzzle of the rifle to the object aimed at. The more the trajectory deviates from this perfect flatness the shorter will be the dangerous zone, because the higher the bullet has to rise the more perpendicular will be its line of descent. This will be readily understood from the diagram on the next page.

In this figure the dangerous zone of a bullet travelling along No. 1 trajectory would only extend from C and E to O for cavalry and infantry respectively; for one on No. 2 it would extend from B and C to O; and for one on No. 3, the flattest trajectory, it would extend from D to

o for infantry, and for its whole course for cavalry. The flatter the trajectory, therefore, of a projectile, the more effective it is in covering the ground. But other desirable conditions also result from flatness of the trajectory. Flatness of trajectory can only be obtained by increase of ve-

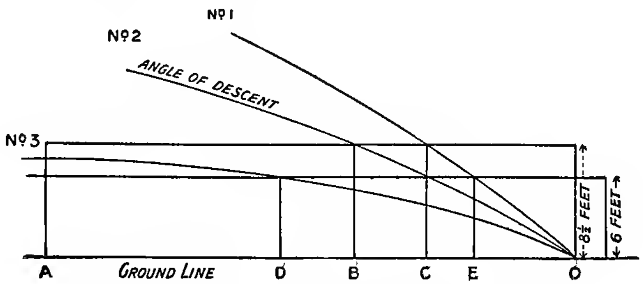


FIG. 10.—Trajectories, showing effect of flatness of trajectory.

locity, and this includes harder hitting and greater destructive power. And again, the less elevation is required in aiming, the less individual judgment comes into play, and therefore the greater will be accuracy of the shooting.

The height of the culminating points of the older rifles was extreme: the bullet of a Snider rifle sighted to 2000 yards rises 866 feet above the line of sight, and that of a Martini-Henry, over a similar range, 357 feet; while the highest point to which a Lee-Metford bullet reaches on a 2000 yards' range is 194 feet. The advantages of a flat trajectory, then, are as follows—(1) greater accuracy in shooting; (2) harder hitting, because of the higher velocity; and (3) greater efficiency in covering the ground, in consequence of the more extended dangerous zone.

Recoil.—When the power is ignited in the rifle the pressure of the powder gas is exerted in all directions, and the effect becomes apparent in the movement of the bullet forwards and of the rifle itself backwards. This backward motion of the rifle is called its "recoil" or kick. Recoil varies inversely as the weight of the rifle: the heavier the rifle the less the recoil, and *vice versa*. Recoil is a thing to be avoided in a rifle, as it tends to lessen the accuracy

of aim; it therefore necessitates rifles being made of sufficient weight, within limits, to obviate its effects.

From all these considerations it would therefore appear that, as regards small-arms, the object of the present day is to obtain a rifle from which bullets can be projected with the greatest possible initial velocity, combined with the greatest power of overcoming the resistance of the air, and thus obtaining the flattest trajectory and the greatest destructive effects at all distances; while the same conditions which tend towards these advantages tend also towards reducing recoil to a minimum, and to ensuring a maximum of accuracy in shooting. Simplicity of the mechanism of the breech-action, and the selection of one which will stand exposure on service and the carelessness of the soldier, are also, no doubt, points taken into consideration in the manufacture of rifles. All these conditions have to a great extent been arrived at in the modern small-bore rifles; but experiments are still being carried out, and further improvements are still likely to be achieved.

The Lee-Metford Rifle.—Three successive "Marks" or patterns of the Lee-Metford magazine rifle have been ap-approved of, each differing in some minor details from its predecessor. Mark I. of this rifle was approved in December 1888. Some changes were made in the method of sighting of Mark I., and Mark I.* was approved in January 1892. Mark II. was approved in April 1892, the principal differences between it and Mark I.* being that the magazine holds 10 instead of 8 cartridges, the weight is less by 4 ounces, and the highest sighting is for 2800 instead of 2900 yards. The Lee-Metford Mark II. rifle is the weapon now (1897) in the hands of the British soldier.

The Lee-Metford Magazine Rifle Mark II.

Rifle.—Weight, magazine empty = 9 lbs. 4 oz.
Capacity of magazine = 10 rounds.
Twist of rifling = 1 turn in 10 inches to the left.
Sighting = 200 to 1800 yards on leaf sight on barrel; 1600 to 2800 yards on dial sight on left side of stock.
Diameter of bore = 0.303 inch.

The Lee-Metford Bullet.—Length = 1.25 inch.
Maximum diameter = 0.311 inch.
Weight = 215 grains, ± 3 grains.
Material of core = 98% of lead and 2% of antimony.
Envelope = cupro-nickel, formed of 80% of copper and 20% of nickel, with 0.5% of iron added.
Charge = cordite, 31 grains, ± 1 grain.
Muzzle velocity of bullet = 2008 f.-s.

The "drift" of the bullet to the left, due to the rifling, is about 1 foot at 1000 yards, and 1.5 foot at 1200 yards. No allowance is made for this in the sighting, as the amount is so very small as to be practically inappreciable, considering the much greater effects produced on the bullet by a side wind.

From a musketry point of view, the Lee-Metford rifle is one of the most powerful weapons supplied to any army.[1] Its trajectory is very flat, and therefore its dangerous zone is extensive; although sighted only to 2800 yards, its projectiles range to a much greater distance, and are effective at 3500 yards.

To compare the curves of the trajectories of the Martini-Henry and of the Lee-Metford rifles: the culminating point of the projectile from the former weapon at a 1500 yards' range reaches 178 feet above the line of sight, while that of the latter is only slightly over 81 feet. At a 500 yards' range, that for which the lowest or fixed sight can be used, with the Lee-Metford the bullet never reaches a distance from the ground greater than the height of an ordinary man when standing; while at a similar range the bullet of the Martini-Henry culminates at a height of 13.2 feet. The bullet of a Lee-Metford would therefore, using the lowest sight, be likely to hit a man at any point inside 500 yards; whilst the Henry-Martini bullet would travel above a man's head under similar circumstances, between the end of the first 100 yards and the beginning of the fifth. The point-blank range of the Lee-Metford rifle is

[1] The only European rifle which to any extent excels it is the Mannlicher of Holland and Roumania, the calibre of which is 0.2569, with a muzzle velocity of 2395 f.-s.

therefore any range under 600 yards; that of the Martini-Henry is only 400 yards. The advantage in the extent of the dangerous zone at the more extreme ranges, as well as at all other ranges, of the small-calibre rifle, over those of the older rifles, is equally well marked. The Lee-Metford rifle is accurate in its shooting; it is hard-hitting; it has a flat trajectory, and therefore an extended dangerous zone; it has great power of penetration, and may be said to be one of the most effective of the modern small-arms. Colonel G. V. Fosbery, V.C., concludes his paper on this subject, read at a meeting of the Royal United Service Institution in May 1891, by saying: "For the present you may rest satisfied to know that our soldiers of to-day hold in their hands the best military small-arm in existence." This is the opinion held by musketry experts; what the faults, if any, of all small-bore rifles, from other points of view, may be, will be alluded to later on. The annexed table shows the various characteristics of the different modern small-arms.

BREECH-LOADING MAGAZINE RIFLES OF SMALL CALIBRE.

(*From "Text-Book for Military Small-Arms and Ammunition." Official copy.*)

Country	Austria, Bulgaria, and Greece.	Belgium.	Denmark.	England.		France.
Pattern of the year	1888–90.	1889.	1889.	1889.	1891.	1886.
Designation	Mannlicher.	Mauser.	Krag-Jorgensen.	Lee-Metford. Mark I.	Lee-Metford. Mark II.	Lebel.
Magazine system	Fixed vertical box.	Detachable vertical box.	Fixed horizontal box.	Detachable vertical box.		Tube in fore end.
Number of cartridges in magazine	5	5	5	8	10	8
Charger or clip	Clip.	Charger.	Charger.	....		....
Cut off	No.	No.	Yes.	Yes.		Yes.
Safety bolt	Yes.	Yes.	No.	No.		No.
Weight—						
Without bayonet	9 lb. 11 oz.	8 lb. 9½ oz.	9 lb. 6 oz.	9 lb. 8 oz.	9 lb. 4 oz.	9 lb. 3½ oz.
With "	10 lb. 8¼ oz.	9 lb. 9½ oz.	9 lb. 13½ oz.	10 lb. 7½ oz.	10 lb. 3½ oz.	10 lb. 1½ oz.
Length—						
Without bayonet	4 ft. 2.4 in.	4 ft. 2.6 in.	....	4 ft. 1.85 in.		4 ft. 3.12 in.
With "	5 ft. 0 in.	5 ft. 0 in.	....	5 ft. 1.45 in.		5 ft. 11.84 in.
Barrel—						
Length ... in.	30.12	30.67	32.9	30.197		31.496
Calibre ... mm.	8	7.65	8	7.7		8
Calibre ... in.	.315	.3012	.315	.303		.315
Number of grooves	4	4	6	7		4
Depth " " in.	.00787	.0032	.0055	.004		.0059
Rifling—						
Twist— 1 turn in ... ins.	9.842	9.842	11.811	10		9.45
" " calibre	31	32.7	37.5	33		30
Direction of twist	To right.	To right.	To right.	To left.		To left.
Sights—						
Lowest for— Metres or paces	300 paces.	500 metres	300 metres.	183 metres.		250 metres.
Yards	246	547	328	200	200	273
Highest for— Metres or paces	3000 paces.	2000 metres.	1900 metres.	2650 metres.	2560 metres.	2000 metres.
Yards	2460	2187	2078	2900	2800	2187
Cartridge—						
Length ... in.	2.992	3.07	2.992	3.05		2.953
Weight ... grs.	455	441	404	415		447
Bullet—						
Material of— Core	Hard lead.	Lead.	Lead.	Hard lead.		Hard lead.
Envelope	Steel lubricated.	Cupro-nickel.	Cupro-nickel.	Cupro-nickel.		Cupro-nickel.
Length ... in.	1.252	12.12	1.181	1.25		1.26
Diam. (max.) "	.3228	.311	.3228	.311		.3228
Weight ... grs.	244	219	237	215		216
Charge—						
Weight ... grs.	42.44	47	33.95	30.5		41.66
Value of— W/D²	.334	.338	.332	.326		.299
Muzzle velocity—						
F.-s	2034	2034	1968	2000		2073
Chamber pressure—						
Tons on sq. in.	19.7	19.7	15.1	15		17.75

Country	Germany.	Holland.	Italy.	Portugal.	Roumania.	Russia.	Spain.	Switzerland.	Turkey.
Pattern of the year	1888.	1892.	1891.	1886.	1892.	1891.	1892.	1889.	1890.
Designation	Pattern 1888.	Mannlicher.	Mannlicher-Carcano.	Kropatschek.	Mannlicher.	"3 Line" Pattern 1891.	Mauser.	Schmidt-Rubin.	Mauser.
Magazine system	Fixed vertical box.	Fixed vertical box.	Fixed vertical box.	Tube in fore end.	Fixed vertical box.	Fixed vertical box.	Fixed vertical box.	Detachable vertical box.	Detachable vertical box.
Number of cartridges in magazine	5	5	6	9	5	5	5	12	5
Charger or clip	Clip.	Clip.	Clip.	....	Clip.	Charger.	Charger.	Charger.	Charger.
Cut off	No.	No.	No.	Yes.	No.	No.	No.	Yes.	No.
Safety bolt	Yes.	Yes.	Yes.	No.	Yes.	Yes.	Yes.	Yes.	Yes.
Weight—									
Without bayonet	8 lb. 6 oz.	9 lb. 0¾ oz.	8 lb. 6 oz.	10 lb. 3 oz.	8 lb. 7½ oz.	8 lb. 13 oz.	8 lb. 9½ oz.	9 lb. 8 oz.	8 lb. 9½ oz.
With "	9 lb. 4 oz.	10 lb. 0 oz.	9 lb. 2 oz.	....	....	9 lb. 7¾ oz.	....	10 lb. 7 oz.	9 lb. 15½ oz.
Length—									
Without bayonet	4 ft. 1.21 in.	4 ft. 2.4 in.	4 ft. 2.50 in.	4 ft. 4 in.	4 ft. 0.24 in	4 ft. 2.79 in.	4 ft. 2.2 in.	4 ft. 3.24 in.	4 ft. 0.6 in.
With "	4 ft. 9.28 in.	5 ft. 5 in.	5 ft. 2.50 in.	....	....	5 ft. 8¾ in.	5 ft. 0 in.	5 ft. 3 in.	5 ft. 6.6 in.
Barrel—									
Length ... in.	29.134	31.1	30.75	31.633	28.74	29.922	29	30.709	29.134
Calibre ... mm.	7.9	6.5	6.5	8	6.5	7.62	7	7.5	7.65
Calibre ... in.	.311	.2569	.2569	.315	.2569	.3	.2756	.2952	.3012
Number of grooves	4	4	4	4	4	4	4	3	4
Depth " " in.	.0047	.0059	.006	.0075	.0059	.0059	.0053	.0039	.0049
Rifling—									
Twist— 1 turn in ... ins.	9.45	7.874	9.238	11	7.874	9	8.66	10.63	9.842
" " calibre	30.4	30.6	36.1	35	30.6	30	31.54	36	32.7
Direction of twist	To right.	To right.	To right.	To right.	To right.	To right.	To left.	To right.	To right.
Sights—									
Lowest for— Metres or paces	250 metres.	400 metres.	400 metres.	300 metres.	400 metres.	400 paces.	400 metres.	300 metres.	250 metres.
Yards	273	437	437	328	437	310	437	328	273
Highest for— Metres or paces	2050 metres.	2100 metres.	2000 metres.	2200 metres.	2100 metres.	2700 paces.	2000 metres.	2000 metres.	2000 metres.
Yards	2242	2296	2187	2406	2296	2096	2187	2187	2187
Cartridge—									
Length ... in.	3.24	3.056	3.267	3.189	3.058	2.992	3.07	3.05	3.07
Weight ... grs.	421	346.4	331.8	546	350	363	373.5	424	416
Bullet—									
Material of— Core	Hard lead.	Hard lead.	Hard lead.	Hard lead.	Hard lead.	Hard lead.	Hard lead.	Hard lead.	Hard lead.
Envelope	Steel, coated with cupro-nickel, or cupro-nickel.	Steel, coated with nickel.	Cupro-nickel.	Steel.	Steel, coated with cupro-nickel, or cupro-nickel.	Cupro-nickel.	Steel, coated with nickel.	Steel envelope point.	Cupro-nickel.
Length ... in.	1.22	1.236	1.24	1.279	1.236	1.19	1.196	1.13	1.212
Diam. (max.) "	.3189	.2637	....	.3228	.2637	.307	.2843	.3189	.311
Weight ... grs.	227	162	163.5	248	162	214	172.8	211.5	213
Charge—									
Weight ... grs.	42.44	36.26	31.6	70 (black powder).	36.26	33	37.8	30.865	40.2
Value of— W/D²	.325	.335	.335	.34	.335	.306	.313	.337	.325
Muzzle velocity—									
F.-s	2034	2395	2395	1750	2395	2034	2288	1968	2139
Chamber pressure—									
Tons on sq. in.	21	....	17.1	15.75	....	10.15	22.3	17.1	19.7

[*To face p.* 28.] At end of Chap. I.

CHAPTER II

THE CHARACTERISTICS OF THE INJURIES PRODUCED BY PROJECTILES

Small-Arm Projectiles.—The characteristics of the wounds produced by bullets vary very considerably according to the shape and size of the missiles of which they are the results, and even more especially in consequence of differences in the rates of velocity at which they may have been travelling at the moment of impact. The spherical leaden bullet of the smooth-bore musket was, perhaps, in diameter the largest small-arm projectile used in warfare, while, at the same time, it was the slowest traveller. Since the musket was discarded and the rifle substituted, bullets have steadily decreased in weight and diameter, while their velocity has been greatly increased; and with these changes the features of the injuries produced by them, both in soft parts and in bone, have become modified.

The Musket-Bullet.—The old round bullet, at its highest rate of velocity, made an entrance wound in the skin the edges of which were surrounded by a wide area of contusion, rendered apparent after a short time by ecchymosis. The skin showed distinct evidence of loss of substance, a circular portion of about the same diameter as the bullet itself being punched out, the edges of the aperture being inverted. The track through the soft parts was much lacerated and contused, and its diameter was usually greater than that of the bullet.

The exit wound was always greater in extent than that on the entrance side; it hardly ever showed the punched-out appearance seen in the entrance wound, but was formed of triangular flaps of skin everted, evidently burst outwards by a pressure from within. The punched-out appearance above referred to is altogether dependent on the velocity

of the bullet. When the velocity is high and when the bullet strikes fairly at right angles, it is always produced; when it is low, the entrance wound in the skin may be formed of triangular flaps, as is the exit wound, the corners of which are inverted. Round bullets so rapidly lose their velocity that by the time they have reached the exit side they may only have sufficient energy remaining in them to enable them to force their way out; the action on the elastic skin being slower, it has time to stretch and give way; the punched-out appearance is therefore absent. With small-bore bullets, on the other hand, the velocity of which is so much higher and so much better maintained, the punching effect is more often seen on the exit side than is the case with spherical bullets. This appearance is due to actual loss of substance in the skin, a circular piece of about the diameter of the bullet, or a little less, being punched out.

Effects of the Old Spherical Bullet on Bone.—The comminution of the shaft of a long bone when a fracture is produced by a round bullet, although much less than that seen to result from the modern projectile, is very different from the average specimen of a "comminuted fracture" caused by other means. The great force exerted on the part, and its directness, break the bone into a much larger number of fragments, the displacement of which is much greater. The fragments are driven forwards at the same time that they are displaced up and down the limb, and as they move they tend to turn over on their shorter axis; thus the disturbance of the parts is very great. Added to this comminution, many fissures in the bone may extend in both directions from the seat of fracture. When the velocity of the missile is low it may flatten against the bone, sometimes not even causing a fracture of the bone itself. A spherical bullet striking the cancellous structure in the ends of long bones, usually simply drills a hole through it with little or no comminution or fissuring. Referring both to the shafts and to the articular ends of long bones, the spherical bullet, owing to its low rate of velocity and its large diameter, is prone to lodge.

The Cylindro-Conoidal Bullet.—Bullets projected by rifled fire-arms have a very much increased penetrative power as compared to that of the older spherical bullet. Two circumstances in connection with the more modern missile explain this fact: (1) it has at the moment of impact a much higher remaining velocity; and (2) it is cylindro-conoidal in shape—it has, in fact, a sharp-pointed head, which facilitates its penetrative action. The area of impact of a smooth-bore musket bullet was 0.75 inch, whereas the greatest diameter of the Martini-Henry is only 0.45 inch. This fact alone goes a long way towards explaining the greater power of penetration possessed by the latter; moreover, the head of the Martini-Henry is conical or wedge-shaped.

Then, again, as the capability of a moving body to do work or to overcome resistance (penetration of the tissues in this case) increases as the square of the velocity, and as the velocity of the cylindro-conoidal projectile is, at all distances, far greater than that of the spherical bullet, so it is evident that its penetrative power will be greater in a corresponding degree. This statement applies in an equal degree whether bone or merely soft parts be referred to. The work a projectile is intended to accomplish is destruction of animal tissues; the greater its energy, that is (in the case of bullets), the greater its velocity, the more completely will it accomplish this end.

Some authorities have been inclined to attribute the increased penetration of rifle-bullets to the spin they obtain from their following the twist of the grooves of the barrel, considering that they, as it were, bore or screw their way through the tissues. But it is impossible to allow that even any small fraction of the power of penetration of these bullets can depend on their rotatory motion. The Snider bullet, at the instant of leaving the muzzle, has a rate of spin which causes it to make one complete turn on its long axis in 78 inches of its onward course. Supposing, therefore, that the part of the body penetrated be 10 inches thick (a high average), the bullet would only have time to make ⅛ of a turn while traversing it, if at its very highest

rate of rotation. Under similar circumstances the Lee-Metford bullet would just make one complete turn, and even in this case the power of penetration of the projectile can hardly be said to depend in any appreciable degree on its motion of rotation. Rotation does not impede penetration, but neither can it be suggested as a cause of great penetrative capacity. Increased energy and a more suitable form of bullet-head are sufficient to account for the fact; other reasons are unnecessary.

Wounds of Soft Parts.—Cylindro-conoidal bullets, in traversing soft parts, produce tracks in which contusion and laceration are far less marked characteristics than is the case in those resulting from spherical projectiles. In the latter case the tissues forming the sides of the tracks are devitalised to a considerable depth, and the parts are lacerated by the large round-pointed body having been driven through; whereas in the former the tissues are more cleanly cut.

The apertures in the skin made by the two kinds of bullets exhibit similar differences. In the case of the cylindro-conoidal bullet, the ring of contusion around the edges of the entrance wounds is much less marked; except at short ranges, the entrance wound itself is less in diameter than the bullet, and, at all but the very longest ranges, it shows actual loss of substance in the skin, a circular piece being punched out. The exit wound is always a little larger than the entrance wound; at short ranges it frequently shows the punched-out appearance usually only seen on the entrance side, because the cylindro-conoidal bullet, unlike the round ball, frequently preserves sufficient velocity to cause this effect; otherwise the exit aperture is formed of everted flaps of skin. The contused and lacerated condition of the sides of the tracks made by spherical bullets necessitates a certain amount of sloughing of these tissues in the process of healing; it therefore happens that suppuration must usually occur in wounds produced by them, and that healing by first intention hardly ever occurs. Sir Thomas Longmore states that he has never seen a musket-bullet wound heal by this direct

method. On the other hand, healing by first intention frequently takes place in the less lacerated and contused wounds of soft parts caused by such bullets as that of the Martini-Henry, and is the rule in those resulting from the modern small-bore projectiles.

Bone Injuries by the Cylindro-Conoidal Bullet.—The amount of injury produced in a bone when fracture results from a bullet, depends largely on the velocity of the missile; the splintering of the bone, the fissures made in it, and the loss of substance at the site of fracture, all are great as the rate of velocity is high. A cylindro-conoidal bullet travelling at nearly its highest rate of velocity comminutes the diaphyses of long bones into smaller and far more numerous fragments than does the round ball; the actual site of fracture is completely cleared of splinters, the ends of the broken bone being separated by a more or less wide space due to complete loss of substance. The fragments of bone are driven apart in lines radiating from the long axis of the bullet track, and up and down the limb; and some of them may be forced out through the skin on the exit side, through secondary exit wounds as well as through the exit wound itself. In this case the exit wound may be of almost any dimensions, from large masses of bone fragments and muscular and tendinous tissue bursting it outwards, and to the surface of these soft parts so driven outwards splinters of bone and bone dust may be seen adhering. The condition just attempted to be described, is the result of the so-called "explosive effects" of a rifle-bullet travelling at almost its highest rate of velocity; but this explosive effect will be more fully referred to later on.

At lower rates of velocity, that is at longer ranges, the fragmentation of the diaphyses of bones is less, and it lessens as the range increases; the fragments are also larger, less numerous, and less displaced; but when bone is fractured the exit wound is always larger than when this does not occur. So certainly is this the case that MM. Delorme and Chavasse, of the Val de Grâce, state that an exit wound the diameter of which is equal to that of the thumb or

index-finger, is indicative of comminuted fracture with free splinters.[1]

In the cancellous structure of the epiphyses of long bones, and in bones wholly formed of cancellated bone tissue, the destruction caused by cylindro-conoidal bullets is less than that seen in the more dense and brittle shafts of long bones. At high rates these missiles fracture the cancellous epiphyses into many fragments, but these latter are not so much separated and dispersed as are the splinters of the shaft; some of the fragments may, and usually are, of large size, but there is always considerable pulverising of the soft bone tissue, and much bone dust is found at the exit side, fragments of large size being usually absent. At longer ranges the ends of long bones may be simply drilled through, little or no splintering or fissuring taking place. At short ranges the effects of such bullets as those of the Snider and Martini-Henry rifles on human bone are most destructive; as the range increases, which is synonymous with saying as the velocity decreases, these destructive effects steadily decrease. At short ranges, up to about 200 yards, the so-called explosive effects are seen; from thence onwards (in range) the amount of comminution into fragments, the displacement of these fragments, the tearing of the periosteum, and the extent of injury done generally on the exit side lessen as the distance from the firing-place increases. The diaphyses of long bones are more minutely fractured than are their articular ends, because the former are more resistant than the latter; and it is admitted that, so long as a projectile is possessed of sufficient energy to overcome the resistance offered to it, the greater the resistance the greater will be the destructive effects produced by its passage through animal tissues.

The Injuries produced by Modern Small-Bore Bullets.—The term "small-bore" is a relative one: the Snider was a small-bore as compared to the smooth-bore musket, the Martini-Henry as compared to the Snider. In the present time any rifle the calibre of which is .350 inches, or less, may be defined as a "small-bore."

[1] *Archives de Médecine et de Pharmacie Militaire*, vol. xvii., 1891.

Since small-bore rifles were first adopted as military weapons, the effects produced by their projectiles, and the amount of injury caused by them in human tissues, have been matters about which very great differences of opinion have been held by men quite competent to form just ones, and the points in dispute can by no means be considered as set at rest at the present moment. It has been held by some authorities that weapons of such small calibre as those now in the hands of European soldiers are unsuited for their purpose, because the wounds they inflict are so trivial in ther nature and heal so rapidly that the desired object is not attained by their use against an enemy; that, instead of placing a man *hors de combat* for such a length of time as will prevent his taking any further part in the campaign, the modern projectile wounds a man in so slight a degree that after a few days or a few weeks he returns to his place in the ranks as capable of fighting as ever. Other writers, however, describe the injuries resulting from the modern projectile of small calibre as so terrible in extent and so fatal in their effects that, in their opinion, the weapons from which they are discharged contravene, in the spirit, if not in the letter, the undertaking entered into by nearly all the civilised powers, at St. Petersburg, in 1868, not to use small-arm explosive shells in warfare. The data on which our present ideas on this subject have been formed have, for the most part, been derived from experimental research, and unfortunately experiments, as they must, from the necessities of the case, be made, do not give similar results to those observed under the actual conditions existing in war.

Experimental Work with Small-Bore Rifles.—Experimental research for the purpose of ascertaining the effects of the new rifles of small calibre on animal tissues has passed through many phases; different conclusions have been arrived at, and statements considered to be final have been made as each series of experiments, carried out under different conditions, has been completed. In England some experiments were made by firing Lee-Metford projectiles into the carcasses of recently killed horses, with

full service charges, at ranges of 100 and 1000 yards; these were reported on by the late Surgeon-Colonel C. H. Y. Godwin, A.M.S. On the Continent experiments were made, using fixed ranges (15 to 20 m.) and reduced charges, the powder being so reduced in quantity as to impart to the bullets, at these short distances, the velocities they actually possess at any given range. To explain what is meant by "fixed ranges and reduced charges"—suppose it is desired to observe the effect of a bullet on an object at 1000 yards' distance. The "remaining velocity" at 1000 yards with the service charge of the projectile of the particular rifle under trial is known, and so much powder is placed behind it as will impart to it a similar velocity at the "fixed range" of, say, 15 yards. At first sight it might be supposed that, as the bullet would strike the object with the same velocity it would have had if it had been discharged with a full charge and had traversed 1000 yards, the effect would be the same; but this is now known not to be the case. Delorme and Chavasse, in France, Kocher, at Berne, Paul Bruns and others employed this method, using both dead animals and dead men as targets.

The third phase in this inquiry consisted in using full service charges at actual ranges against human cadavers.

This method was employed by Demosthen, of Bucharest, Von Coler, Schjerning, and others. Different results as to the gravity of the injuries resulting from small-bore bullets were arrived at by experiments carried out under these varied conditions, and very opposite opinions were formed by the different experimenters. No doubt the methods of Demosthen and Von Coler most nearly approached the conditions which obtain in actual warfare; but it is becoming evident that even these may convey erroneous impressions, for it is now apparent that conclusions drawn from experiments made on dead animals or men are not borne out by what is observed when living men are wounded by small-calibre projectiles. Whether this is because dead animal tissue is harder and more resistant, the fats having solidified and the liquids being greatly diminished in quantity, or from some other cause,

is not just now quite certain; but it is steadily becoming more and more evident that the appalling destruction produced in dead animals and cadavers by small projectiles tried in any of the ways above referred to, is not experienced when men are hit by them under the ordinary conditions.

A series of experiments were carried out at Enfield in 1889, under orders of the War Office, with the Lee-Metford rifle firing (1) a bullet with a soft lead core and an envelope of ferro-nickel, and (2) a bullet with a hardened core of lead, 98 per cent., and antimony, 2 per cent., and a cupro-nickel envelope, against the carcass of a horse. The late Surgeon-Colonel Godwin reported that "these two projectiles acted on the soft and bony tissues of the horse exactly as if they had been shells: in no instance was there any clean-cut perforation through bone. The range was 100 yards. The Lee-Metford bullet, at 100 yards, did most terrible execution: the knee, thigh-bone, and the shafts of other bones were completely shattered." In one case the femur was grooved at the upper end; fissures extended from the point of impact to the middle of the bone, where a transverse fracture occurred, whence fissures extended into the joint below. "In a second experiment, at 1000 yards, these bullets made clean holes through the breast-bone, and passed through the femur without shattering it." It was frequently found that the ferro-nickel-covered bullet broke up on contact with bone, and was found in the pulped muscles in the form of minute particles of the metal. The bullets with the thicker cupro-nickel envelope, such as are now used, for the most part preserved their shape, and did not break up. The wounds caused by them at short ranges were most extensive and destructive; the bones were pulverised and splintered for long distances, the fissures in some instances extending from the point of impact into the joints above and below, while the muscles and other soft parts were torn and pulped. At long ranges the injuries were less severe.

Experiments were also made in France with the Lebel and Gras rifles, of .315-inch and .433-inch calibres respec-

tively, by MM. Delorme and Chavasse, of the Val de Grâce.[1] The Lebel bullet has a core of hardend lead and a cupro-nickel envelope; that of the Gras is of hard lead without an envelope. The explosive effects at short ranges were similar with both missiles, up to 300 yards with the Lebel, and up to 150 yards with the Gras. At distances outside the zone of explosive effects, between 300 and 800 yards, the Lebel bullet smashed the bone into numerous small pieces, but did not drive them so far apart as did the Gras bullet; but otherwise, at the ranges named, the gravity of the fractures produced by these two bullets was about equal. From 800 to 1200 yards the comminution caused by the Lebel is less than that resulting from the Gras bullet, free splinters are less numerous, the separation in the fissures is less pronounced, and the projection of fragments through the exit wound is less considerable; hence these fractures are less severe. At ranges over 1200 yards the bullet of .315-inch calibre produced more severely comminuted fractures than did that of .433-inch calibre.

In the articular ends of long bones, fractures, perforations, &c., of the same characters were produced by both bullets; but, setting aside explosive effects, the smaller bullet caused less extended fissuring, smaller fragments with less separation, and more frequently simple perforation. Wounds of joints were, in general, less comminuted and less severe with the Lebel bullet; indeed, with equal velocities the small-calibre bullet, beyond the explosive zone, generally produced on bone less destruction and less grave injuries. These experiments were made, apparently, at a fixed range with reduced charges.

Paul Bruns experimented with the Belgian Mauser rifle bullet of .311-inch diameter, having a cupro-nickel envelope, against cadavers, using reduced charges at a fixed range. There were 30 shots through soft parts only, and 100 through bone; of the latter, 84 were injuries of the diaphyses of long bones. He states that "the exit wound in the skin very often shows a rent more or less extended, measuring from 2 to 10 or 15 centimetres. An exit wound

[1] *Archives de Médecine et de Pharmacie Militaire*, vol. xvii.

of over 3 centimetres is evidence of bone lesion; at the same time a small exit wound does not exclude bone injury. The penetrative power of the small projectile is enormous: against the human body, up to 1500 yards, it never lodged in the tissues. The Mauser, of .311-inch calibre, is an efficient army weapon; it has a long range, and answers all requirements in an astonishing manner. The bullet is capable of passing through the bodies of several men and rendering them *hors de combat*. Its high rate of initial velocity increases not only the shock (concussion) but also the explosive effect in compact and liquid tissues, to which must be attributed the great damage done by it at short ranges." Bruns' experiments led him to believe that at ranges over 300 m. the small-calibre bullet hardly ever becomes deformed, while between 400 and 1500 m. it, as a rule, makes a wound with a very small passage, with very small apertures at the points of ingress and egress, and with very little shattering of bones or tearing away of the soft parts. These wounds almost all bear a subcutaneous character, and since the bullet, or parts of it, seldom or never remain in the body, they may readily heal without suppuration.

Bruns is to a certain extent a firm believer in the "hydraulic pressure" theory as explanatory of the so-called explosive effects of rifle-bullets at short ranges: he says, "The greater the velocity the greater is the destruction due to hydraulic pressure," and "The destructive effect of hydraulic pressure on the human body is greater as the walls surrounding the tissues are stronger." His experiments go to show that explosive effects are less often the result of hard-mantled bullets than of leaden ones. A difference is clearly made manifest by using soft leaden bullets, which can change their shape and become deformed. As regards the more resisting bones, Bruns admits that the hydraulic theory is insufficient; for he says, "Explosive effect in compact bones is only explicable by admitting a transference of some of the energy of the bullet to the neighbouring tissues, which thus produce a lateral or explosive effect; the great rigidity of the compact bones is

the cause of the explosive effect." "My experiments," he continues, "tend to reduce to its proper value the effect of hydraulic pressure, to which, until lately, too great an importance has been given.

The difference between the small-bore and the .433-inch calibre rifles is, that the former has greater penetrative power and less explosive effect. At long ranges the injuries seen in the cancellous structure of long bones and in flat bones are grooves and clean perforations without fissuring or actual solution of continuity; as the distance increases, the fissuring and fragmentation diminish, and the diaphyses present trenches and canals. The zone of grooves and punched-out injury of bone is from 440 to 1200 or 1550 yards. "As, in future, most fights will take place at these distances, so the conditions will be more favourable towards cure; the small tracks will allow wounds to heal without suppuration. That projectiles do not often lodge, removes a source of inquietude to the wounded, and of embarrassment to the surgeon, and allows of rapid healing under an antiseptic dressing. The small bullet also produces fewer lesions of vessels, and primary and secondary hæmorrhage will be less frequent than in wounds resulting from the softer bullets, which deform more easily. Lastly, it is of importance to consider what kind of bullet is best calculated to destroy resisting obstacles, while it is itself least liable to undergo deformation: should the steel or cupro-nickel covered projectiles have the preference? At 330 yards the leaden bullet deforms on striking soft parts, and up to 1300 yards on striking bone. Our experiments prove that the cupro-nickel-mantled bullet deforms only on striking the hardest bone, at the same time its forward end becomes turned back or flattened, with rupture of the envelope and powdering up of the core. On the other hand, the steel-covered bullet deforms but little, and never lets slip the core. Even on stone parapets it has been but little changed in shape, and, as many wounds in war are caused after ricochets, this is of importance. We therefore prefer the steel envelope. In fine, we should receive with joy the intro-

duction of the small-bore bullet, and especially the *projectile à chemise*. It coincides with humanitarian ideas. Future wars will probably produce a large number of wounded; but, on the other hand, the wounds will be clean and even, and, on account of the narrow track, will have a subcutaneous character. Cure will be easier, and fewer men will be mutilated and crippled. The new arm of small calibre is not only the best, but it is also the most humane, in that it lessens the horrors of war as far as possible" (Bruns).

Dr. Demosthen, of Bucharest, an army surgeon, made experiments in 1893 with the Mannlicher rifle of .256-inch calibre, the bullet having a hard lead core and a steel envelope. He used full service charges at *actual ranges* against living horses and dead men. In his results he found that the bone injuries, which is the point about which difference of opinion principally is held, were more severe than Bruns' experience had led him to believe. "In wounds of the skull, at short ranges, the explosive effects are very marked; and we may say that, at all distances, they are seen in skull injuries when full charges are used: reduced charges in these cases produce different results." The diaphyses of long bones, at long and short ranges, are fractured with much comminution, this having been exemplified by the fact that quite similar fractures were produced in the humerus at 110 and at 1540 yards. Demosthen does not believe in the hydraulic action of the bone marrow, as has been suggested, as explanatory of the extreme comminution of long bones, but attributes it to the great resistance offered to the passage of the projectile. Even in the epiphyses he has not seen mere tunnelling, but the bone fragments are always partially held together by the periosteum. And he thus sums up his conclusions: "In 65 wounds of men and horses, in all anatomical situations, and at distances from 5 to 1540 yards, I have only seen true perforations in three flat bones in horses; only one human bone showed it, a skull with the brain removed. Wounds of vessels show large losses of substance, and give rise to enormous hæmorrhages. In wounds of

the lungs the bullet track is smaller in dead than in living animals, and hæmorrhage is always great, even when no important vessel is implicated."

The difference in the conditions under which these two sets of experiments, Bruns' and Demosthen's, were carried out, consists principally in the fact that in the former case they were made at a fixed short range with reduced charges, while in the latter full charges were used at the actual distances required. At first sight it would appear to be certain that a bullet discharged with a reduced quantity of powder, entering a limb from a distance of 15 yards with the velocity it is known to have at, say, 1000 yards when fired with a full charge, would cause the same amount of destruction as though it had actually traversed that distance before striking; but the weight of evidence is distinctly against this conclusion. For some reason, the nature of which is not very apparent, bullets propelled by the full charges, and striking at the real distances, do more damage to dead animal tissues, and more especially to bones, than when fired under the other conditions. Simple perforations of the epiphyses of long bones are stated to be the rule at medium ranges with reduced charges, while they only occur at long ranges with full charges. Bruns (reduced charges) mentions "trenches and canals" as occurring in the diaphyses at ranges between 400 and 1500 m., while Demosthen has never seen clean-cut perforations of the diaphyses under 660 yards; and the German report does not refer to them at any range, but states "at 2200 yards the diaphyses are still fractured and fissured, though the fragments are less displaced." Von Coler, under whose direction the German experiments were carried out, claims a marked increase of the destructive effect for bullets fired under actual conditions as to powder and range, over that reported to have been observed from bullets fired with reduced charges.

The German report just referred to contains the results obtained and the conclusions drawn from an extended series of experiments made by Von Coler and Schjerning at the suggestion of the German Minister of War. It is

probably the most valuable evidence at present available as to the injuries resulting from the modern small-bore rifle. The weapon used in the great majority of cases was the German "Pattern '88," of .311-inch calibre, giving an initial velocity of 2034 ft.-s.; the bullet has a hardened lead core and steel or cupro-nickel mantle, and weighs 227 grains. In some few cases a rifle of still smaller calibre was used. Full charges at real distances were employed throughout. Nearly 1000 shot injuries were obtained in the series, the report of which includes details of injuries produced on dead men, living animals, and at least 22 cases of wounds accidental, suicidal, and otherwise, which occurred in living men. The conclusions arrived at are as follows: little or no difference exists between the injuries inflicted on living and on dead bodies; the extent and the character of the comminution of the bones, the sizes of the entrance and exit wounds in the skin, and also the tracks through the muscles, the perforations in the intestines, the breaking up of the cranium, were identical in both cases, or at any rate showed only such slight differences as might be neglected. It is incorrect to assume, as Bruns did, that there are certain fixed zones for the effect of bullets, and that a distinction can be drawn between a zone of explosive effect, a zone of full effect, and a zone of decreasing power, as being sharply divided from each other according to the range. The power of a bullet does not vary by bounds; its effect, as the range increases, is quite steadily and gradually diminished, and examination of wounds in all anatomical situations shows that a gradual and perceptible diminution of the effect of the bullet takes place as the range increases. Different parts of the body offer different resistances according to their construction and physical condition, and therefore one part may, at a given distance, receive very serious and complicated damage, while another may be simply perforated; but this does not invalidate the statement that the severity of bullet injuries decreases gradually with the range.

Next to the range, which is synonymous with saying next to the velocity of the bullet, the conditions which are

of most importance in determining the damage done are the firmness, the consistence, and the amount of moisture in the structures traversed by the missile; as these are more or less marked, so is the destructive effect more or less pronounced. The entrance and exit holes in the skin decrease in diameter as the distance increases. As regards this point the German report agrees with the observations of Delorme and Chavasse, Bruns, Steinburg, Ellenberger, and Baum; and is against the expressed opinions of Habart, Bogdanik, Chauvel, Nimier, and Kikuzi, who contend that the skin wounds increase in size as the range increases, and are small at short ranges, unless the skin happen to have bone or other resistant tissue immediately beneath it. Von Coler attributes the contrary experiences of the latter observers to the fact that they used reduced charges.

The Entrance Wound in the Skin.—The entrance holes in the skin vary in diameter directly as the velocity of the projectile. They are usually circular in shape, but this to a large extent depends on whether the skin at the point struck is loose and badly supported beneath or the reverse. Circular entrance perforations result from bullets striking perpendicularly and punching out a disc of skin; up to 2200 yards they form about 40 per cent. of all hits examined, at short ranges they are about 25 per cent., and over 1100 yards the percentage increases to 60 per cent. The edges of these punched-out holes are, as a rule, smooth and sharp; but where the skin is loose and not stretched, the entrance wounds may have a jagged or star-shaped edge. Then, on the other hand, the average size of these openings may be exceeded when bones lie immediately beneath the part of the skin struck. When the bullet strikes obliquely, the hole it makes is usually oval, and sometimes triangular or four-cornered; in these cases the edges are irregularly split and jagged. Any deflection of the bullet from its straight line of flight, which causes it to strike more or less with its side, or any deformation in its form or tearing of its envelope, such as always results from a ricochet, causes it to produce an irregular and lac-

erated entrance wound. The extreme edge of the entrance hole usually shows a black or dark-grey colour from deposited powder dirt; but when this has been removed a white rim will become visible, where a ring of cuticle has been removed by friction of the bullet. The rim of true skin so exposed soon dries and becomes brown in colour. This ring of brown colour is never seen at the edge of the entrance wound directly after the receipt of the injury, but it always makes its appearance when the part has had time to dry.

The Exit Wound in the Skin.—While the size and shape of the entrance wound depend almost entirely on the velocity and angle of incidence of the bullet at the moment of impact on the skin, the variations in the condition of the exit wound, although influenced by the same characteristics, depend, in addition, on the qualities, especially as regards power of resistance, of the tissues through which it has passed, and on the amount of damage it has caused within them. When it has passed through *soft parts only*, the exit wound is usually a circular punched-out hole, but its edges are slightly shreddy and torn. In about 10 per cent. it is triangular or star-shaped, this being due to the bullet making a slight turn and coming out somewhat sideways. On the whole, variations in the exit aperture are more common than those observed at the entrance side. When the skin is loose, and its elasticity can take effect, lacerated tears and three- or four-sided wounds are caused, and these are more common at long ranges. When the bullet has passed through bone, circular exit holes are uncommon, but do occur occasionally. They are in a large majority of instances star-shaped and lacerated (fig. 11). A bullet which even grazes the diaphysis of a long bone without causing fracture, is sure to be turned slightly from its direct line of flight and to come out sideways, thus making a large exit hole, probably star-shaped or triangular, or three- or four-sided. When it passes through the compact tissue of a long bone, the exit wound may be a laceration of almost any dimensions, several inches in length, with torn edges, shreds of muscles and tendons

protruding, and with particles of bone débris adhering to its mangled sides. Exit wounds of this kind are only produced at ranges up to 600 yards, and they are always signs of perforation of the diaphyses of long bones. Delorme and Chavasse state that an exit wound admitting a thumb indicates a comminuted fracture, and Steinburg infers a similar condition from a wound of over 1.2 inch in length. Von Coler's experiments have, on the whole, justified these conclusions: he believes that exit holes of 1.3 inch denote shots through compact bone; but he qualifies this statement by adding that no conclusion as to the amount of injury within can be arrived at by mere inspection of the exit wound. Small exit holes, produced at short ranges, may often be seen in cases where the bone injury within the limb is most severe. At longer ranges, over 1100 yards, circular exit holes where bones have been hit are exceptional, and moreover the exits are frequently multiple from breaking up of the bullet. At all ranges, and whether bone has been hit or not, the exit hole is usually larger than the entrance.

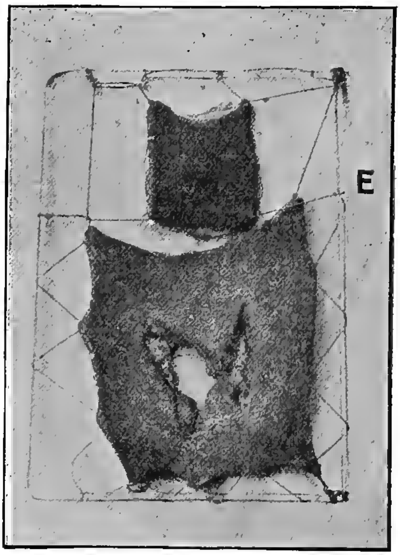


FIG. 11.

Entrance and exit apertures in skin, made by a Lee-Metford bullet which passed through shaft of tibia at fifty yards' range. E = entrance.—*Netley Museum.*

The relative positions of the entrance and exit wounds are almost always correct indications of the track of the bullet. It occasionally happens, however, that a bullet may be so turned aside by grazing a compact bone that this statement does not hold good; but this is quite exceptional. As a rule it will not be wrong to consider the line between

the entrance and exit wounds as the channel of the shot. "No bullets were observed to run in rings or to follow the contours of the body" (Coler).

The Bullet Track through the Soft Parts.—The shot channel through muscles is in the form of a cylindrical tube, cut out as with a punch, the diameter of which at short ranges is somewhat larger than that of the bullet, and which gradually decreases as the distance increases, but it is always larger than the entrance wound in the skin. Its sides are smooth, and their immediate vicinity is engorged more or less with blood as the hæmorrhage is great or small. When the track is long, through thick muscles for instance, there is a gradual increase in size towards the exit side. Sudden enlargements may be seen at situations where a bullet passes through any resisting tendinous structure. Perforations of fasciæ are circular punched-out openings, of about the same diameter as the bullet. Tendons are more often split in the length of their fibres than cut across, while if a bullet strikes sideways, or is much deformed, they may be torn and lacerated so as to completely break their continuity. Their mobility, smooth surfaces, and toughness no doubt often preserve tendons from complete section.

Shreds of Clothing, &c., in Wounds.—The possibility of pieces of clothing being carried into bullet wounds is of some surgical importance on account of the septic influences they would probably have. Experiments have been made by Lagard in America, which tend to show that rifle-bullets are themselves usually sterile, and that their passage through living tissues does not cause septic infection within the bullet track. But the case is different with regard to shreds of the clothing a wounded man may be wearing when hit: these are very likely to be infected with micro-organisms of various degrees of virulence, and the importance of the question whether or not pieces of clothing are carried into bullet wounds can, from this point of view, hardly be over-estimated. Delorme and Chavasse frequently found portions of the clothing of wounded men in the bullet track. Bogdanik also found them where the

injuries had been caused by ricochets when the bullets were deformed and jagged. Habart and Bruns never found them. In the German experiments 12 per cent. of the cases showed penetration of shreds of clothing into the bullet tracks.

Injury to Blood-vessels.—Coler points out that the great majority of injuries to the larger vessels are caused by fragments of bone, and not by the bullet itself. This naturally occurs from the circumstances of the case, a large number of jagged pieces of bone being violently driven, some of them, to long distances through the soft parts. This being so, wounds of vessels produced in this way require no particular attention in an inquiry into the class of wounds resulting from the use of small-calibre rifles: they are like those seen in wounds produced in a similar manner by the older kind of weapon.

Injuries to the larger vessels by the bullet itself were comparatively rare in the German experiments; only about 9 per cent. of the hits examined showing direct injury of the large vessels by the bullet. Neither Coler nor Habart saw any reason to believe that arteries could slip aside and thus escape serious injury by a small-bore bullet; when the situation of the skin wound made it probable that an artery would be found wounded, dissection usually showed that this had occurred. The extent of the injury to the larger vessels depends upon the range, the direction of the hit, whether perpendicular or sideways, and upon the condition of the bullet, whether deformed or otherwise. A mere graze of a vessel, with or without visible sign of injury to its external coat, may cause considerable injury to the inner and middle coats, separating them from the former, and causing fissures to appear in them in the direction of the length of the vessel. Sometimes a clean-cut aperture is made when a bullet strikes nearer the centre of the diameter of the vessel; but complete section and laceration of all the coats are more common, and the probability of this condition is increased at shorter ranges. At long ranges some connection usually remains between the cut ends of the vessel, a circumstance favourable to hæmor-

rhage. Nearly all the hits of vessels observed by Coler were grazing or grooving hits. The aorta of a horse showed the only perforation of a vessel at its greatest diameter seen in his experiments; in this case there were "two smooth-edged gashes," both through all the coats.

Hæmorrhage from direct hits with the new bullet will certainly be more profuse than was the case in similar injuries by the old spherical bullet. Vessels do not slip aside and escape injury by small-bore bullets as they did with round leaden balls, and the fact that the injuries of arteries are clean-cut openings when grazes occur, and smooth perforations when the missile strikes the vessel fairly (not crushed lacerations as they formerly were), will tend to increase the liability to prolonged bleeding. Direct hits of vessels are the more dangerous, because some shreds of tissue always remain and prevent contraction and retraction of the arterial coats, the means which nature employs to starch hæmorrhage. From the characters, then, of the wounds of arteries caused by the modern bullet, it is certain that there will be a larger percentage of fatal cases on the battle-field due to immediate hæmorrhage than was the case when round balls were used.

Injury to Bones.—The injuries produced in bone, and more especially in long bones, have been of peculiar interest to surgeons since the modern rifles have come into use. Fischer has shown that about 22 per cent. of all the gunshot wounds met with in war are complicated by fractures of the long bones. These are the cases, moreover, which give the surgeon cause for his greatest anxiety and care in diagnosis and treatment. Again, surgeons are fairly well agreed as to the kind of injury caused by small-bore bullets in other tissues, while the greatest differences of opinion still exist as to the amount and character of the destructive effect caused by them in the long bones of the extremities.

Experiments with reduced charges demonstrate quite different effects, especially in bones, from those resulting from full charges at actual ranges; but even those authors who have experimented with reduced charges do not agree amongst themselves as to the effect of small bore bullets on

bone. Bruns describes the diaphyses of the long bones as being "certainly splintered" at 440 yards' range, but the splinters are large, well bound together by periosteum, and not scattered about the soft parts nor driven out through the exit wound: there are no extensive centres of laceration in the soft parts on the exit side. From 880 yards there are, according to Bruns, marks of grazing caused by bullets and simple perforations without splintering or solution of continuity in the diaphyses, and the frequency of these increases with the range. Habart, on the other hand, failed to produce simple bullet holes in the diaphyses at any range. He describes "explosive effect" on an extensive scale as the rule up to 330 yards, as being rarer up to 550, and as occasionally seen up to 825 yards. According to him, from 550 yards to 1320 yards the splinters are larger, less displaced, and, from the latter range, better held together by their periosteum. Delorme and Chavasse report exceptional cases of explosive effect even at 880 yards when the bullet happened to strike a particularly compact diaphysis. They found the splintering decreased with the range; but even at 1320 yards the pieces were small, and driven into the surrounding soft parts.

Demosthen, of Bucharest, who was the first to use full charges at actual ranges, found splintered fractures in the diaphyses at all ranges; he did not find any great differences in the amount or kind of splintering, and never saw a clean-pierced hole under 660 yards. Coler and his colleagues "very soon convinced themselves that the reduced charge, generally speaking, produced not the same, but less injury than was caused by rounds fired with full charges at the distances with which the reduced charges were intended to correspond." Their experiments showed gradually decreasing effect from range to range as the distance was increased. The greatest destruction was at 37 yards, and the least at 2200 yards. Hits at ranges up to 220 yards are distinguished by extensive destruction of the bones and of the soft parts behind them. The bone is crushed over a large extent into small and generally loose splinters, some of which are found in the cavity made by

the bullet, but which are for the most part forced into the soft structures which lie behind the exit hole in the bone, tearing and destroying them up to the exit wound in the skin, through which many splinters are forcibly driven. Bone dust is found along the exit channel mixed with shreds of torn muscle as well as with splinters of various sizes, most of them being small.

The nearer the bullet strikes the bone at its greatest diameter the greater is the destruction produced both in the bone and in the soft parts beyond; but even with grazing shots most severe splintering of the bone and extensive pulping of the soft parts are observed. The lacerations of the soft parts and the extent of the cavity formed on the exit side have a distinct relation to the amount of injury to the bone. Up to 110 yards bone splinters are usually small and loose; at 660 yards the splinters are larger in size, and the lacerated cavity in the soft parts is smaller and seldom extends to the exit in the skin. At 770 yards the exit holes in the skin are smaller and seldom exceed from .7 inch to 1.18 inch in diameter. At 1100 yards the bullet sometimes fails to perforate hard bones, and is somewhat deflected from its direct line of flight, with the result that extensive lacerations of soft parts are caused, but the splinters made in the bone are larger and for the most part remain in position. At 1320 yards splintering of bone and laceration of the soft parts on the exit side are the rule, but the extent of these conditions is much diminished. At 1760 yards the splinters are very large and less numerous, while they remain in position, held by their periosteum: the injury to the soft parts on the exit side is correspondingly less. At this range bullets begin to remain in the wound. At 2200 yards this happens more frequently, but even here it is not the rule, and splintering of the bone is constantly present. Simple bullet holes through compact bone were never found even at 2200 yards in the German experiments; while those authors who used reduced charges report them as frequent at ranges as short as 660 yards.

The fragments into which compact bone is reduced by

bullets may be divided into three groups: fine bone débris caused by actual contact with the bullet; small splinters up to 1.5 inch in length, which arise from the exit side of the bone; and larger fragments, which are usually seen on the entrance side of the shaft. Coler states that the "intensity of the splintering"—by which, I presume, he means the number of fragments into which the bone is broken—diminishes with the range, but not its longitudinal extent. At ranges from 54 to 2200 yards he found about the same lengths of bone splintered. The smaller splinters, which are usually loose, are the principal cause of laceration of soft parts: they are numerous as the range is shorter; after 1760 yards they were seldom found. The larger fragments usually lie about the entrance hole in the bone or on its lateral walls.

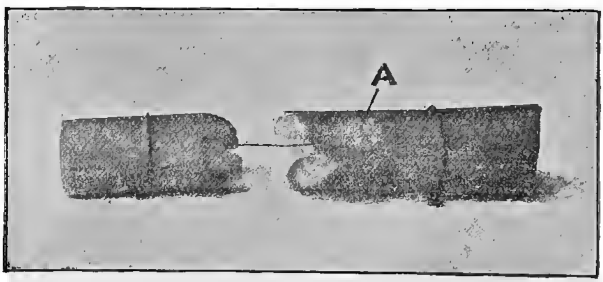


FIG. 12.

Fracture of shaft of femur from a graze by a Lee-Metford bullet. A=site of contact with bullet.—*Netley Museum.*

The higher the rate of velocity of the bullet, and the harder the bone, the more numerous are the lines of splintering which run from the entrance and exit holes in the bone. Up to a range of 660 yards the bone marrow is quite removed from within the splintered area, but at longer ranges some of it remains. Grooving shots are almost always accompanied by splintering of the entire thickness of the bone, the splintering being more marked as the groove is deeper. Even mere grazes cause fissuring and splintering with complete solution of continuity up to 2200 yards, and the shallowest grazes often cause simple

transverse fracture at some little distance above or below the point of impact, the periosteum remaining untorn. Fig. 12, a fracture of the shaft of the femur caused by a graze (A) of a Lee-Metford bullet, shows this perfectly.

Coler is very clear in his opinion that the bullet wounds seen in living men are quite similar to those produced experimentally in dead bodies, though this does not agree with our present small experience of what occurs in actual warfare with small-calibre rifle-bullets, for so far the injuries have been described as being much less severe. On the other hand, this may have been due to the ranges having been long; for little or no attention has been paid to this very important factor in reports of wounds observed after an engagement.

The fractures made in other especially hard bones, the spine of the scapula, the inferior maxilla, the zygoma, the ischium, &c., are of quite the same kind as those seen in the diaphyses of the long bones.

Injuries of the Epiphyses and of Spongy Bones.—With these also the extent of injury decreases as the range is longer. At short ranges, up to 220 yards, the entrance hole is small, of about the same diameter as the bullet, with smooth edges; the exit hole is two or three times as large, and on this side the splintering is severe. From both holes fissures extend which usually interrupt the continuity completely. On the exit side are found bone dust and small splinters driven into the lacerated soft parts. The periosteum is frequently untorn over the fissures, and keeps the fragments bound together. When a bullet does not pass through the greatest diameter of an epiphysis, there may be no solution of continuity, but merely fissuring and splintering of the side struck. From 660 yards clean-cut tunnels may be seen, with fine fissures at the entrance side and small splinters at the exit: from 880 yards onwards this kind of fracture is more frequent. At 1760 yards tunnels without fissuring or splintering are first observed, but even at this distance bullet injuries of the epiphyses are not always of this favourable character.

Every hit through the cancellous structure of a long

bone does not necessarily include implication of the neighbouring joint; the fissuring does not always extend to the cartilages, and does not invariably lay open the capsule. Simple perforations of the capsule are more common with the new bullet than with the old. In the German report two cases are referred to of living men, in which the knee-joint was laid open without any injury to the bones forming it. When a bullet perforates the epiphysis close to the joint, a network of cracks may be found traversing the surface of the cartilage coating the end of the bone. This favourable condition is found more often in the knee than in other joints. Simple capsular perforations have been found in the knee, but not in the shoulder, elbow, wrist, ankle, or hip: hits on these joints nearly always show loose splinters within the joint cavities; up to 660 yards bone dust, and at longer ranges larger splinters and particles of cartilage. The condyles of the humerus are especially hard, and for this reason wounds of the elbow are peculiarly liable to be complicated with severe fractures and by loose splinters in the joint.

Experiments with rifle-bullets on animals cannot be compared with those on human beings, since the resistance offered by the two kinds of bones is different; and one great factor in determining the destructive effect of a bullet is the resistance offered to it, the other being the velocity of the missile.

Injuries of the Skull and Brain.—In experiments with bullets on the skull the results obtained form two groups, which are clearly divided and quite different from each other: those in which the skull was empty of brain matter, and those in which, as in ordinary conditions, it was full. In the German series the bullet always perforated the skull up to 2970 yards; this was the nearest range at which the bullet failed to pass out. The results in skulls filled with sawdust, powdered gypsum, or other compressible substance containing air, were in every way similar to those obtained with empty skulls. The entrance was a clean-cut punched-out hole, with some short, fine fissures through both tables, but no extensive injuries or lines of cracking;

it was circular when the bullet struck perpendicularly, oval when it struck obliquely, and about the same size at all ranges.

The exit hole was hardly ever circular; it was oval, triangular, four-sided, or irregular in shape, and it varied much in size. The only explanation of this is that the bullet had been deflected slightly from its direct line in perforating the entrance side, and struck at the exit side obliquely, and therefore with a more extended surface. Fine cracks radiated for short distances from its edges, but there was never any extension of injury to other bones than those actually pierced. The size of the exit hole merely depended on the angle of incidence of the bullet and on the hardness of the portion of bone hit.

The results of bullet wounds of the skulls of living men or in the full skulls of dead men are altogether different from those just referred to. "A full skull fired at at 54 yards was completely shattered; the bones and scalp were torn into the smallest atoms and scattered in all directions. The entire base of the skull was broken up into separate pieces of bone, the lines of fracture of which only partially corresponded to the natural sutures. There was nothing left of the brain but a pulpy substance mixed with fragments of bone, in which some individual convolutions of the brain could still be recognised" (Coler). In bullet wounds of the head at very short ranges, the entrance and exit wounds can be defined as such; the roof of the skull is broken up, and the sutures burst apart, but the lines of fracture follow no regular order; the scalp for the most part preserves its continuity, and shows apertures only at the entrance and exit holes, from which brain matter protrudes.

Even at 110 yards diminution of the destruction is observed; the extent of the injury is not so visible outside; but if the skull be handled, the shattering of its roof and sides can be distinctly felt, and the splinters perceived to crepitate against each other. Brain matter protrudes at the exit wound, but rarely at the entrance side. From range to range, as distance increases, a regular and steady

decrease occurs in the amount of damage to the bony roof. Zones of splintering around the entrance and exit holes continue, but lines of fracture unconnected with these apertures, though present, become less numerous. From 1100 yards the lines of fracture are radial about the entrance and exit holes, and at 1760 yards they begin to cease to be observed, though one line of fracture which joins the two apertures is always apparent up to this distance. At 1320 yards splintering around the entrance and exit holes is still fairly extensive; but at 1760 yards a clean-pierced entrance hole was first observed in a full skull, similar in all respects to one seen in a skull from which the brain had been removed. But even at 1760 yards' range this simple perforation without cracks and fissures was not constant; for out of three hits at 2200 yards, one showed distinct lines of fracture between the entrance and exit holes.

As in the case of the long bones, so in that of the bones of the skull, the effect of small-bore bullets is a steadily decreasing one with the distance. At very short ranges (54 yards in the German experiments) almost the whole of the upper part of the head may be blown away. But setting aside cases of this kind, at short ranges all the bony case of the brain, vault, sides, and base, is traversed irregularly in all directions by cracks and fissures, some of which are in immediate connection with the entrance and exit holes, the others branching off from these primary lines of fracture. As the range increases, the destructive effect gradually lessens; the fissures decrease in number, until at 1760 yards a clean-cut perforation first appears.

Cases which apparently do not follow this general rule, cases in which the damage is found to be greater or less in degree than the particular range would seem to justify, are explained by the great variations which we know to exist in the thickness and hardness of the bones of the skull at different points. More extensive damage may be done at a longer range than at a shorter one if the hardness and resistance of the bone at the point of impact be greater in the former case than it is in the latter. Bruns speaks of skull injuries as showing explosive effects up to ranges of

440 yards, and simple bullet holes without splintering at ranges over 880 yards. Habart, Chauvel, and Nimier fix the range, in which explosive effect of small-bore bullet hits on the skull are seen, as being between 440 and 550 yards; and the different results obtained in the German experiments may be explained by the fact that in the latter full charges were used, and in the former reduced charges were employed at a short fixed range; for, in a trial shot with a reduced charge, giving the bullet the velocity it would have at 770 yards, Coler also produced a simple perforation without splintering, while with full charges severe splintering and fissuring were produced, without exception, up to 1320 yards. Demosthen, in Roumania, even goes further, and concludes that bullet hits on the skull produce practically the same effect at all ranges.

The destruction which occurs to the brain itself from bullet hits is, at short ranges, enormous. This is evidenced not only in the immediate neighbourhood of the bullet track, but throughout all the mass of the brain, a considerable quantity of which is driven out through the entrance and exit apertures. As the range increases, the injury to the brain diminishes so rapidly that even at 110 yards the bullet may make a small cylindrical channel through it. The shot which produced the least destructive effect in the brain, in Coler's series of experiments, was fired at 700 yards.

The "Stopping Effect" of Small-Bore Bullets.—Fears have been freely expressed as to the capability of small-bore rifle-bullets of stopping the rush of a fanatical savage enemy. Medical officers who served in the Waziristan and Chitral expeditions of 1895, where Lee-Metford rifles were first used in warfare, and Mr. H. C. Thomson,[1] who wrote the history of the latter campaign, state that the English small-bore cannot be depended on to stop a man in his charge. These opinions are held, not from actual experience, but from judging by the trivial wounds produced by Lee-Metford bullets when soft parts only were implicated.

[1] "The Chitral Campaign: a Narrative of Events in Chitral, Swát, and Bajour," by H. C. Thomson, 1895.

In the Waziristan and Chitral campaigns no rushes of the kind under consideration occurred, but the simple wounds of the soft parts appeared so insignificant that these statements regarding the effect of the Lee-Metford bullet appeared to be justified.

No doubt the spherical bullet and the bullets of the older rifles, of comparatively great sectional area, gave a more stunning blow, and were more likely to check a man in a rush; and it is probably correct to say that small-bore bullets which cause wounds of the soft parts only will not have this effect to so great an extent as the larger and heavier projectiles had. But when we remember the great amount of disorganisation which the modern bullets produce in traversing bone, as well as on the contents of the different cavities of the body, at short ranges — and it is only at short ranges that the "stopping effect" is required — it seems difficult to imagine that this apparent defect will prove to be a real one.

The columns of the *Field* newspaper have, for some time past (1895–96), been open to a lengthy correspondence on the subject of the advantages and disadvantages of the .303-inch Lee-Metford rifle as a sporting weapon in big-game shooting in India and elsewhere. In this class of sport the "stopping power" of the rifle is probably of as great importance as accuracy of shooting, and in the letters above referred to this was the point most dwelt upon. The opinions given, and formed on practical experience, varied very considerably, some being in favour of and some against the Lee-Metford as regards its capabilities in this respect, but all agreed as to its great "stopping power" when the bullet deformed on striking. Mr. A. H. Glynn, writing from South Africa, in the *Field* of November 2, 1895, gives most important evidence about the Lee-Metford rifle in this connection. He says that this weapon "is gradually being adopted by big-game hunters, and will soon be the principal rifle used; that it is far superior to any .450-inch or 12-bore rifle for large or small game; and that a man could not have a better rifle for all-round shooting than the .303-inch calibre Lee-Met-

ford." Mr. Glynn uses the "Tweedie bullet," which deforms on striking animal tissues, and he states that it "makes an enormous hole in an animal." To make certain of the Lee-Metford bullet deforming, all that is required is to file away its extreme point so as to open the hard envelope and lay bare the lead. On striking, the envelope is then torn open and turned back in the form of jagged flaps of metal; the leaden core breaks up into slug-like particles, which are scattered in all directions through the tissues, and the wound it produces is of the utmost severity.

Greater "stopping power" than this bullet will have cannot be required in a small-arm. "Stopping power" in a rifle-bullet is only a real necessity in fighting against a fanatical savage enemy, who will advance as long as he is physically capable of doing so; the civilised soldier does not act in a similar manner, and "stopping power" in Continental warfare is only required against cavalry and artillery horses, and we know from experimental research that the injuries produced by the modern small-arm projectile in horses are much greater than those seen in men. But, be the stopping effect of small-bore rifle-bullets what it may, it is highly improbable that any government will ever again adopt a small-arm of large calibre. The tendency is even now in the opposite direction, and experiments are being directed towards rifles of still less calibre than that of the present weapons.

But if it should be decided that the Lee-Metford bullet, in its present form, is defective in "stopping power," it is quite well known to the authorities in this country how in many ways to modify its shape in order to give it this quality in a pronounced degree without interfering with the accuracy of its shooting.

"Explosive Effects."—Since rifled small-arms have come into use in warfare, a large number of wounds have been observed in which the destruction to the tissues has been so enormous that the suspicion that they must have been the results of explosive shells has been, at first sight, warranted. Injuries of this class are usually accompanied by comminuted fractures of bone, especially of the

shafts of long bones. In these cases the destruction of tissue, especially at the exit side of the limb or body, was so extreme that it seemed impossible to consider it as due to a solid projectile, but that, on the contrary, it must have been the result of explosion of the projectile after its entrance.

In the large majority of cases in which these "explosive effects" have been seen, the bullet had encountered compact bone in its passage; but Delorme and Chavasse have reported them as occasionally occurring when soft parts only have been traversed by the bullet. Other authors have not noticed explosive action under the latter condition.

When explosive effect is produced, the exit side of the bullet track is found to be much larger than the entrance side; it may be of almost any dimensions, extending sometimes to a quarter or more of the length of a limb; from the point of the bone on which the bullet first impinged, the track is funnel-shaped towards the exit side; the bone is pulverised to a large extent, and much comminuted, the fragments being driven into the soft parts for long distances, pulping the muscular tissues and lacerating the vessels and nerves; there is considerable loss of substance between the ends of the fractured bone, the immediate site of fracture being quite cleared of splinters, and fissures extending for many inches through both portions of what remains of the bony shaft; a large cavity is formed within the limb, immediately beyond the bone, which is filled with lacerated soft tissues of all kinds intimately mixed with bone dust and small particles of bone splinters; tendons and shreds of muscle hang out of the exit wound, which may be represented by a large aperture bounded by triangular or four-cornered flaps of skin burst outwards, and in the neighbourhood of which there may be other rents in the skin unconnected with the exit wound of the bullet itself, evidences of splinters of the bone having been driven outwards with great velocity. With all this damage at the exit side, the wound of entrance may be so small that the tip of the little finger enters it with difficulty.

This is the class of wound to which the term "explosive"

has been applied; it has all the appearance of having been the result of an explosion within the part. MM. Delorme and Chavasse[1] detail the following lesions in a gunshot wound of the middle part of the thigh due to a Lebel bullet at a range of 320 metres: "At the side of the wound of entrance, which was clean-cut and regular, and hardly of greater diameter than that of the bullet, was a tear through the skin about 4 inches in length, through which the mangled muscles could be seen; the vessels, intact but bruised, crossed the cavity; the wound of exit was represented by a large square laceration of muscle and skin partly held together by shreds of the sciatic nerve; it was 5½ inches long; the seat of fracture was clear of splinters, and showed a loss of susbtance of 3½ inches in length between the ends of the bone." Another injury produced by a Lebel at 280 metres was as follows: "A very comminuted fracture of the femur; entrance wound the same diameter as the bullet; the exit wound as wide and as long as the hand." M. Delorme adds: "This kind of injury explains what is meant by the explosive effect of a solid bullet; it is just as if the wound had been produced by a shell."

In all the campaigns which have occurred since cylindro-conoidal rifle-bullets have been used, wounds of this kind have been frequently observed; wounds which, to all appearances, could only have resulted from small-arm shells, the employment of which has always been considered contrary to the usages of civilised warfare. Even as late as the Franco-Prussian War of 1870–71, the combatants on either side mutually accused each other of using explosive bullets. As a matter of fact neither side used them; and had those persons who accused their enemies of using explosive bullets had more experience of the effects of solid cylindro-conoidal projectiles, these recriminations would not have been made, but the true causes recognised.

So much has been written, since small-bore rifles have been invented, on the so-called explosive effect of rifle-

[1] *Archives de Médecine et de Pharmacie Militaire*, vol. xvii., p. 84.

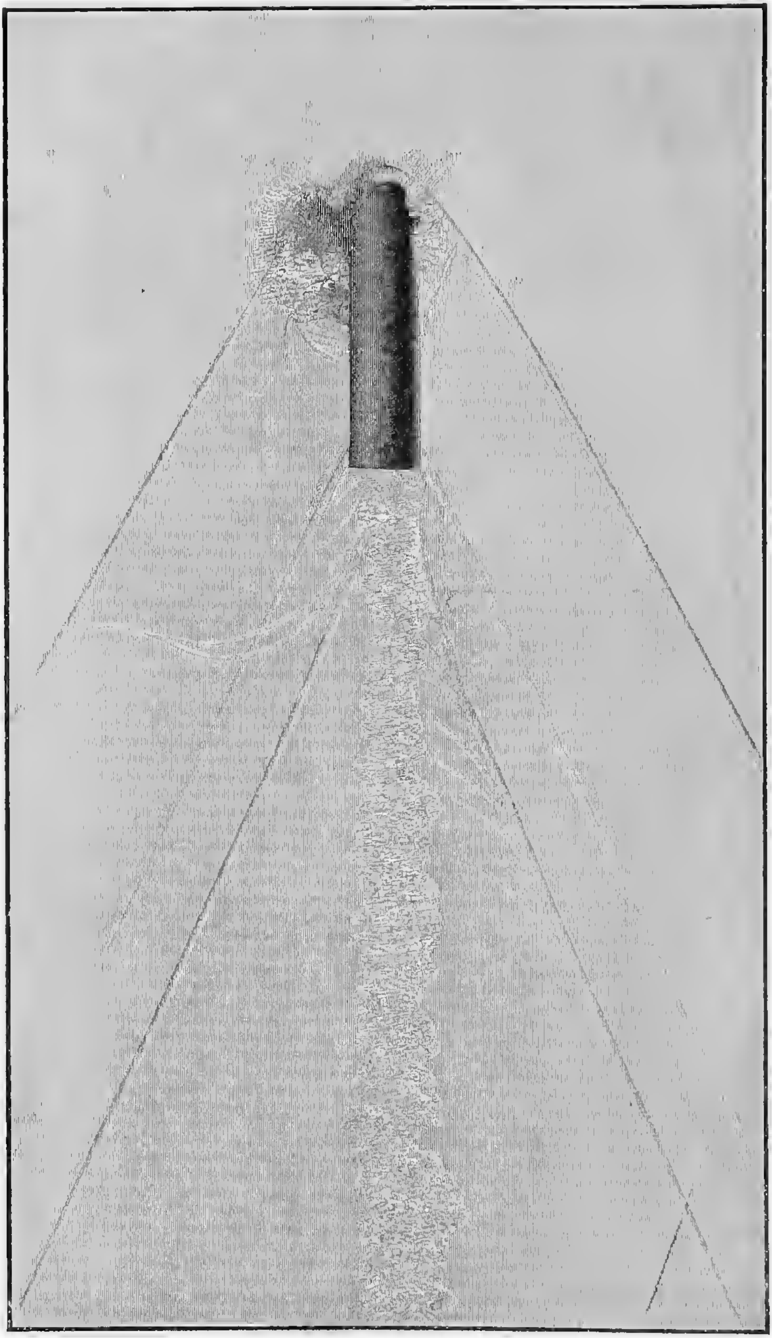


FIG. 13.—Bullet at high velocity, passing through a mixture of carbonic acid gas and ether vapour, a very dense mixture.—BOYS.

bullets, that one might almost be led to believe that this class of wounds is an outcome of the use of the modern bullet of small calibre, and that these extensive injuries were a new feature in gunshot wounds; whereas quite the contrary is the fact. The severity of the explosive effect is, if anything, greater with the older rifle bullets than it is with the new. The softer leaden bullet deformed, on striking, much oftener and in a greater degree than do those of modern days, covered as the latter are with an envelope of hard metal; and deformation has much to do with increasing the extent of a bullet wound, especially on the exit side. On the other hand, cases in which explosive effect is seen are certain to be more numerous with the small-bore rifle than with the Snider, Martini-Henry, Gras, &c., because the projectiles of the former retain their higher velocities over more extended ranges than do those of the latter, and explosive effects only result from bullets still travelling at high rates of velocity. Two conditions are necessary for the production of explosive effect —great velocity in the bullet, and considerable resistance in the parts traversed by it; as these conditions, or either of them, decrease, so the extent of the injury lessens. The Martini-Henry and the Gras rifles cause explosive injuries up to 150 or 200 yards, while the Lee-Metford, Lebel, and other rifles of about the same calibre produce them up to 300 or 350 yards.

The Theoretical and the True Explanations of "Explosive Effect."—Several theories have been put forward to explain the so-called explosive effect of solid rifle-bullets on animal tissues. Of the five principal are as follows:—

1. The theory of hydraulic pressure.
2. " " compressed air, or the projectile air.
3. " " rotation of the bullet.
4. " " deformation "
5. " " heating "

None of these theoretical explanations have now any adherents of importance except the first two, the "hydraulic theory" and that of the "projectile air," and even these are now almost abandoned as insufficient. The me-

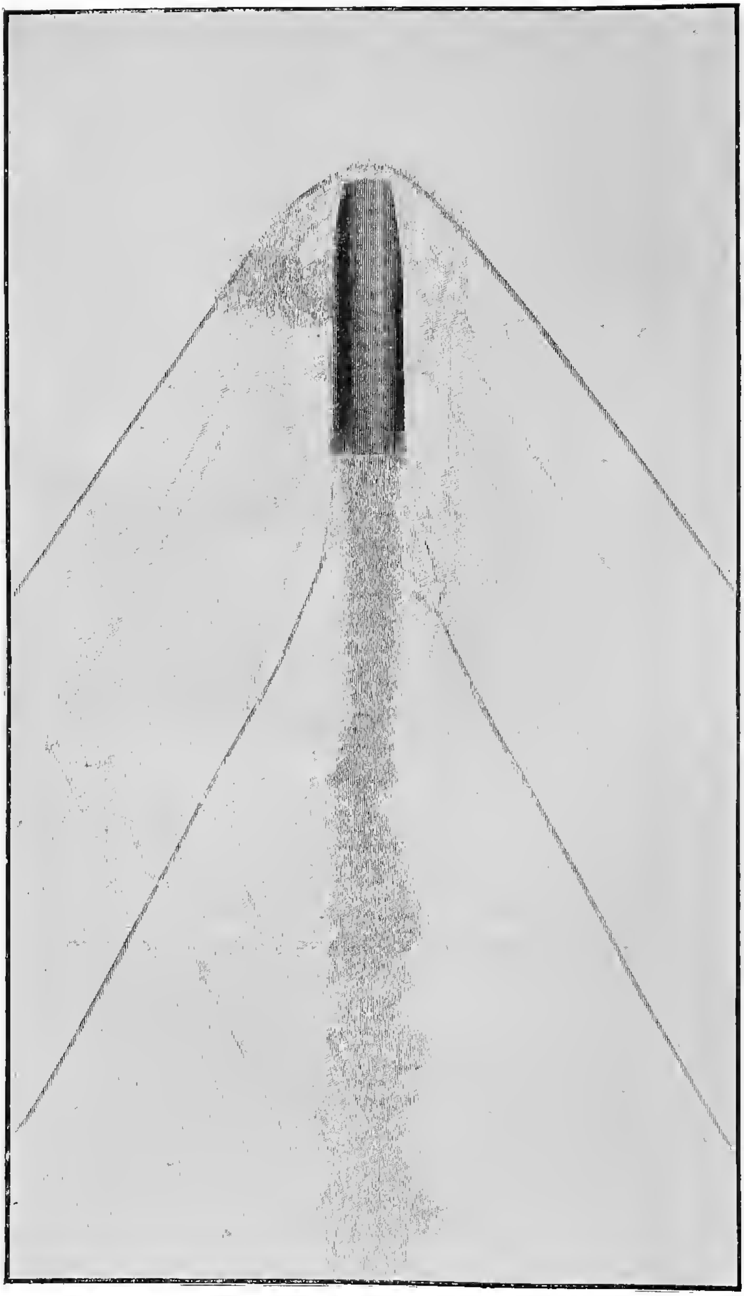


FIG. 14.—Bullet travelling through air, at 2000 ft.-secs.—BOYS.

chanics of the production of gunshot injuries in general are nowadays fairly well understood. Many writers, including Von Beck, Habart, Kocher, Bruns, and Kikuzi, have treated the subject exhaustively in their works, and most authorities are now agreed as to the causation of the destruction which occurs in these cases. But the views propounded by these writers, although sufficient to explain the conditions found in the large majority of gunshot wounds, failed to explain the occurrence of the explosive shots so frequently produced by rifle-bullets at short ranges, and other theories had to be put forward for these exceptional cases. Of the two theories above mentioned, that of hydraulic pressure is the more important, and will require the more detailed reference.

The Theory of the "Projectile Air."—This explanation of the explosive effects seen in some rifle-bullet wounds is a very old one, and had almost been forgotten, until Melsens, professor of physics at Brussels, recently revived it, and, as he considered, supported it by experimental proofs. The idea is this—that a certain quantity of air, in a greatly compressed condition, carried in front of the bullet, actually enters the soft parts of the person struck, even before the bullet impinges on the skin, and, having entered in this highly compressed state, suddenly expands to resume its original volume, and so blows the soft tissues apart. The pad of compressed air in front of the bullet is an ascertained fact, it having been proved by Boys, Mack, and Salcher, who photographed bullets travelling at very high rates of velocity, the pictures so produced showing it in a most distinct manner (figs. 13, 14, 15). But this explanation has had but little acceptance. The truth of the experiments on which Melsens relied as evidence that the air entered before the bullet, has been disproved by further experiments made by an artillery officer at Brussels, and the notion is so far-fetched that but little reliance has ever been placed on it. There is no evidence in the tissues themselves, after a gunshot wound, that air has been forcibly driven into them; it is most difficult to imagine a substance so soft and movable as air, howsoever compressed

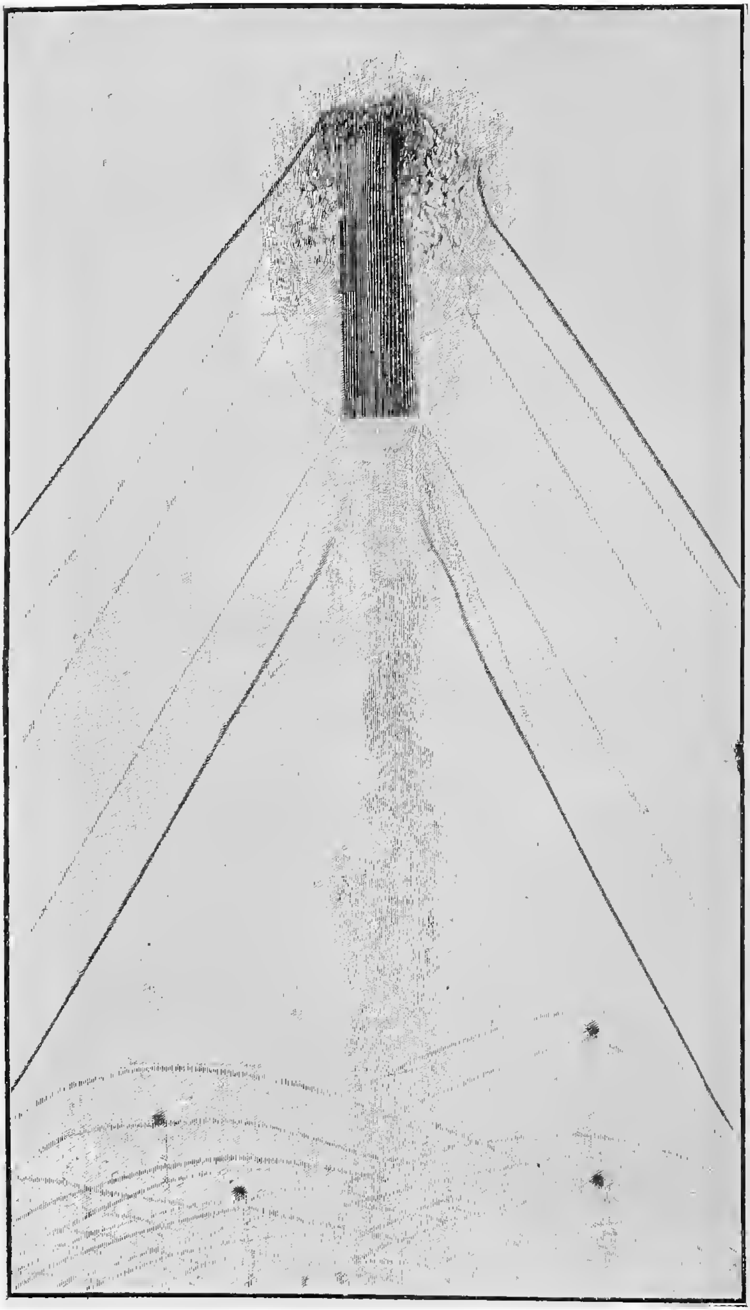


FIG. 15.—This bullet has just passed through a piece of black card-board.—BOYS.

it may be, when free to move aside, being driven through the skin before the bullet; and, even if this were conceivable, what is to prevent its expansion past the sides of the projectile, and so escaping into the open air instead of blowing the tissues apart?

The Hydraulic Theory.—When a projectile is fired through a tin or leaden vessel filled with water and sealed, besides the apertures of entrance and exit of the bullet, other rents and tears are found to have been produced *on all* sides of the vessel, due to the pressure which has been communicated to the liquid within. To the cause of these ruptures the term "hydraulic pressure" has been applied, and this explanation of their occurrence is called the "hydraulic theory." The principle on which the action of the hydraulic press is based depends on the fact that, when a pressure is applied over a certain area to the contents of a closed vessel containing liquid, an increase of pressure is set up within the walls of the vessel; and that the increased pressure so set up is represented by the product of the number of areas on the inner walls of the vessel equal to the area on which the pressure is applied, multiplied by that pressure. Upholders of the "hydraulic theory" as explanatory of the so-called explosive effects of rifle-bullets on animal tissues, look upon a limb or body as a closed vessel containing water, or mostly water, and account for the extreme destruction which results by considering it as due to the enormous increase of pressure caused by the added bulk of the bullet to the incompressible contents of the part hit. But the German experiments have proved that this method of accounting for explosive effect is unsound; for Coler has shown that as much, or almost as much, and certainly quite similar damage is done by a rifle-bullet to the walls of a leaden vessel filled with water but left *open at the top.* In this case it is impossible that the pressure on the inner surface of the vessel can be increased in any appreciable degree, because the fluid is free to escape at one end; and yet the effect as regards damage to the vessel is the same. That it certainly is due to some action which takes place in the fluid is evident, for on

firing through a similar empty leaden vessel no damage is done to it except the production of the holes of entrance and exit; the "hydraulic theory," however, does not explain what occurs.

The condition of the experimental sealed tin or laden vessel when fired into, is quite different from that of a limb or body when traversed by a bullet. The metal vessel is full; at the moment the bullet strikes, it is incapable of receiving any addition to its contents without rupture of its walls; the bullet is driven into it with enormous force, and rupture of its walls necessarily follows, because in them there is no elasticity. The limb, on the contrary, is only apparently full; it is not full in the sense of incapacity to hold more, and unless it were so the "hydraulic" action could not come into play. But Coler's experiment above referred to, of firing a bullet through a leaden vessel filled with water but open at the top, is sufficient to disprove the "hydraulic" pressure explanation of explosive injuries without further discussion; under such conditions hydraulic pressure, properly so-called, cannot be produced.

FIG. 16.
Empty leaden vessel showing aperture of bullet.

Since reading Coler's report, I have made some "control experiments," in order to verify or disprove his statement that open vessels filled with water undergo the same damage from the passage of a bullet at high velocity as sealed ones do, and I have obtained results similar in every detail.

My experiments were made by firing Lee-Metford bullets (cordite cartridges) through leaden vessels, 7 inches high and 4 inches in diameter, filled with water, some being

open and some sealed, at a range of 17 yards. Judging only from the amount of damage and distortion caused to

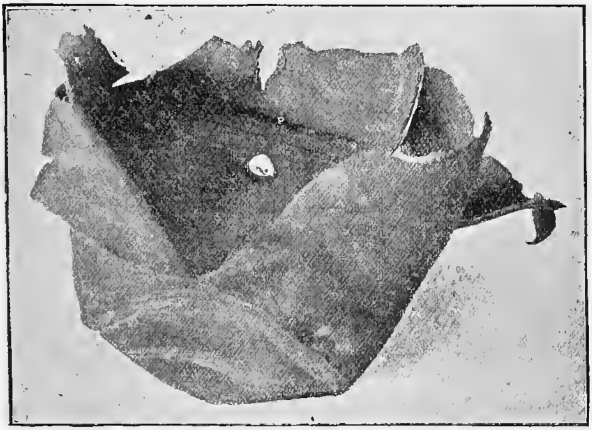


FIG. 17.
Leaden vessel filled with water and ealed.—*Netley Museum.*

the vessels, it is impossible to tell which were open and which sealed. Rents in the leaden walls appear on all sides of both equally, and the metal is twisted and torn in

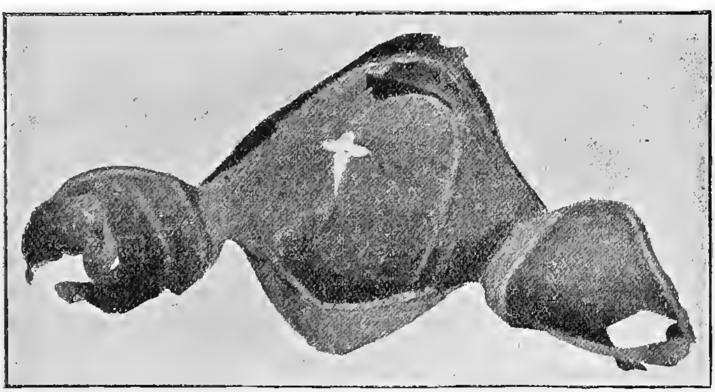


FIG. 18.
Leaden vessel filled with water and sealed.—*Netley Museum.*

every direction, while the exit apertures can be readily recognised on the far side, if the damaged walls of the ves-

sel be replaced as far as possible in their original relation to each other. Whereas, if hydraulic pressure had been

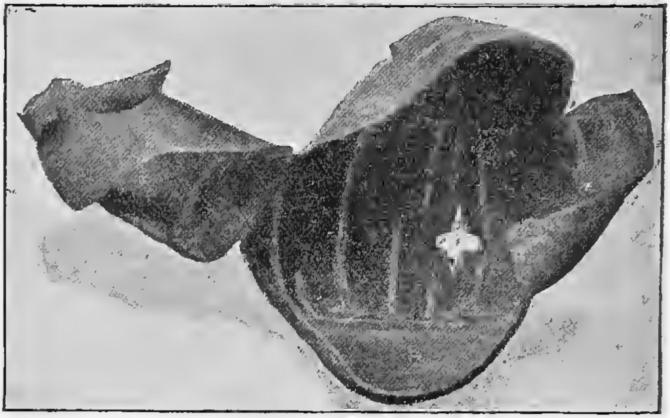


FIG. 19.
Leaden vessel filled with water and sealed.

the cause of the general rupture in the closed vessel, an exit hole could not be produced by the bullet, because the destruction of the walls of the vessel at the exit side would

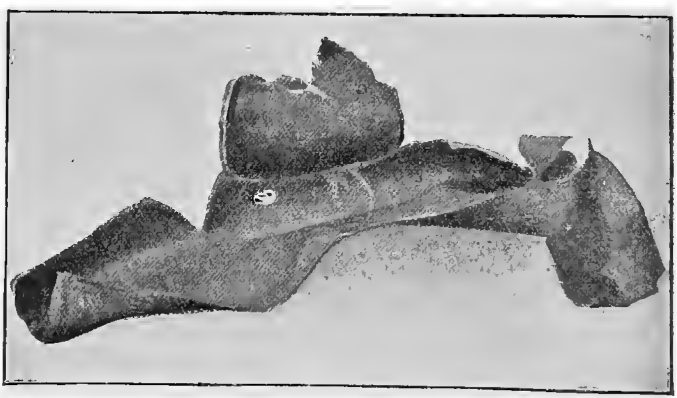


FIG. 20.
Leaden vessel filled with water; not sealed.

have occurred when that force was set up, viz., immediately the bullet entered, and must have been antecedent to the

passage of the projectile. In the illustrations given above, which are taken from photographs made immediately after the experiments, fig. 16 shows one of the vessels fired through in its empty condition; no injuries were produced, except entrance and exit holes, the former of which is shown. Figs. 17, 18, and 19 are from vessels filled with water and sealed, while figs. 20 and 21 are from open vessels.

These results are precisely similar to those obtained by Coler, and the fact that it is immaterial whether the ves-

FIG. 21.
Leaden vessel filled with water and left open.

sels were open or closed, so far as the destructive effect of the projectile is concerned, so long as they were filled with liquid, precludes the "hydraulic theory" as an explanation of the results observed.

The True Cause of "Explosive" Injuries. — The true cause of these severe, apparently explosive wounds, is found in the high rate of velocity communicated to the projectile, which is synonymous with saying that it is the large amount of energy inherent in the bullet at the moment of impact to which the "explosive effects" are due. The very soft parts themselves receive from the bullet a large amount of its energy, and move outwards, in lines radiating from the long axis of the bullet track, with such a degree of force that they act as secondary missiles on the

neighbouring tissues, and cause still further smashing and pulping of the tissues. Even the fluid particles participate in this secondary action, but it is all the more marked when fragments of bone are driven apart in this manner.

In short, bullets travelling at high rates of velocity produce crushing and attrition of the tissues directly and indirectly: directly by the immediate action of the bullet itself, and indirectly by the communication of a part of its energy to the solid and liquid particles which it displaces. Most frequently a bullet which produces the so-called "explosive effects" has struck bone in its course, and has communicated a part of its energy to the fragments and splinters of the bone; but when only soft parts have been traversed, similar results have occasionally been observed. M. Delorme says, judging from his own experiments: "To produce such wounds it is sufficient for us to fire, at short ranges, bullets driven at high velocity which pass through tendinous or aponeurotic regions; the enormous force or energy which the projectiles impart to all the particles, liquid or soft, which they encounter, will account for such injuries." The "short ranges" here referred to are 300 yards and under.

With the new small-bore bullets it was at one time thought that these apparently explosive effects were due to the composite structure of the bullets themselves, consisting, as they do, of a thimble or envelope of harder metal containing a leaden core. In the early days of these bullets, and before their manufacture was as perfect as it is now, the thimble was apt to become damaged and deformed on contact with hard and resisting animal tissues, and when this occurred the leaden core escaped and was found broken up and scattered amongst the muscular and bony débris. The great destruction of the parts was explained by the breaking up and forcible distribution of the particles of lead and envelope. But this is not correct, for experiments have proved that solid copper bullets cause similar effects if driven with equal velocity. We must therefore fall back upon the older explanation that "explosive effects" are due to the energy of the bullet being communicated to the frag-

ments of bone and to the particles of liquid and soft tissues broken up in the bullet track, and that these act as secondary missiles on the part in their vicinity.

In order to put the question of the use of explosive bullets, properly so-called, in warfare on a correct basis (it being universally acknowledged that the real object of the use of weapons of offence in battle is neither to kill men outright, nor to blow their limbs to pieces, but merely to put out of the fighting line or render *hors de combat* the largest number of men possible), a conference was held at St. Petersburg in 1868, which resulted in an agreement by all the principal military powers of Europe "to abstain from the use of all explosive projectiles of less than 400 grammes, or 14 ounces, in weight." This limitation of weight, of course, excluded all small-arm explosive bullets, but did not interfere with the use of shells in artillery fire.

Wounds by Large Projectiles or their Fragments.—The projectiles fired in modern times from large ordnance and artillery field-guns consist almost exclusively of "shells" of one kind or another. An artillery shell may be defined to be a hollow case of steel or cast-iron containing a "bursting charge," the destructive effect of which is produced by the fragments into which the shell is broken, or by the bullets which are set free, by an explosion within it. Shells of many different patterns are used by artillery, but it will be sufficient, from a surgical point of view, to describe two of them, the common shell and the "shrapnel," all others being modifications of these. Both kinds of shell were used with the old smooth-bore artillery guns; they were then spherical in shape, and both are now used with the newer rifled ordnance, and are cylindro-conoidal projectiles of about the same shape as a Martini-Henry bullet.

The common shell (fig. 22) is simply a hollow metal cylinder containing a bursting charge of powder, which is exploded in some cases by means of a "time fuse," and in others by a percussion arrangement which acts only in consequence of the shell's impact against the ground or other hard substance. The injuries resulting from com-

mon shell are caused by the fragments into which the metal case is ruptured, these varying in number from 20 to 50 pieces.

The shrapnel shell (figs. 23, 24) is in outward appearance quite similar to the common shell; but the greater part of the space within is filled with spherical, iron or "mixed—metal" bullets, sometimes of two sizes, in which case the smaller ones are used to fill up the spaces between the larger. The number of bullets in a shrapnel varies with its size; the 12-pounder B.L. service shrapnel contains 177 bullets, 35 to the pound. On the explosion of a shrapnel shell the number of missiles set free is far greater than is the case with common shell, the bullets representing, as it were, fragments of the case already prepared for dispersion in all directions. A shrapnel shell is made up of two portions—the body or cylinder of the projectile, and the head—which are readily separable from each other; the bursting charge, which is placed in front or behind the bullets, being small in amount, as it is not intended to rupture the shell itself, but only to blow off the head or base and thus set free the contents.

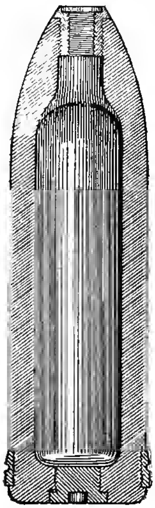
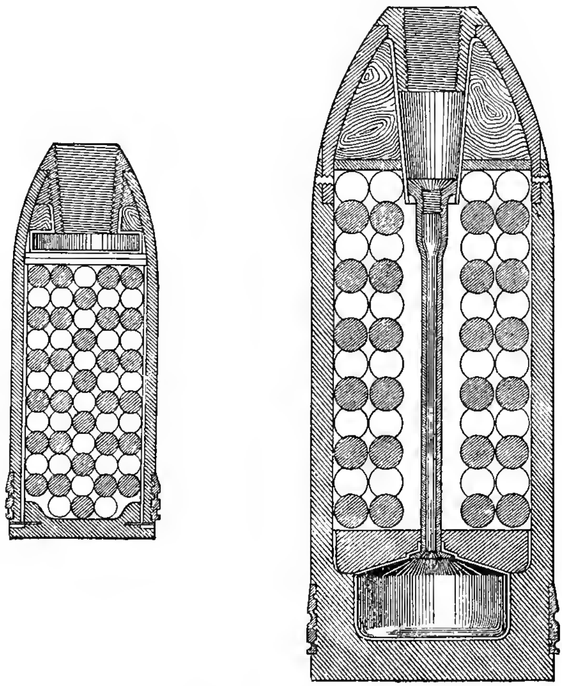


FIG. 22.
Common Shell.

When solid shot were used, it was not uncommon, in consequence of the size and weight of the projectiles, for limbs to be carried away by them, or if the trunk were struck, for death to be instantaneous; but latterly, since the use of shell has become so much more common, these extensive mutilations are not so frequently observed. Shells break up into fragments small and large, which are spread about in all directions and cause a greater number of injuries but of less severe character. The old pattern common shell broke up irregularly into fewer fragments but of a larger size than those of the more modern shrapnel. From 20 to 50 pieces would probably represent the fragmentation of the common shell, while the shrapnel

shell may disperse from 100 to 200 pieces, including fragments of the case when this ruptures, as it occasionally does.

The efforts of artillerymen of the present day are directed towards the construction of shells which will break up into the greatest number of pieces, because the more a shell breaks up, the greater will be the number of



FIGS. 23 and 24.—Shrapnel.

men hit and the more widespread will be the results, but, as a necessary consequence, the intensity and gravity of the individual wounds will be lessened.

Common shell are not used primarily by artillery for the purpose of killing and wounding the enemy—though they frequently do this also—but in order to ascertain the range of the position to be shelled, and to destroy earthworks and forts. The smoke of the explosion of a com-

mon shell is visible at any distance suitable for artillery, and the gunner judges the accuracy of his estimation of the range by observing whether his shell explodes at or beyond or within the required distance; he then substitutes shrapnel, unless his object be to pound down earthworks or other defensive cover. The perfection of the use of shrapnel is that the projectiles should explode from 50 to 100 yards in front of the enemy; whereas common shell should penetrate and bury themselves in the works against which they are used before explosion takes place, the object of their use being not so much to cause injury to men as damage to the cover which protects them from other kinds of projectiles, and to indicate the range.

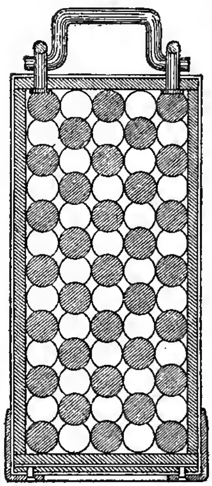


FIG. 25.—Case-shot.

Case-shot (fig. 25) is a projectile similar in principle to shrapnel: it is a thin metal case containing from 100 to 300 round leaden balls hardened by antimony. "Case" contains no bursting charge within it, but is ruptured close to the muzzle by the explosion of the powder charge within the gun; the bullets thus set free spread out like a charge of shot from a fowling-piece, and are very destructive to masses of men at short ranges, *i.e.* up to 300 or 400 yards with field-guns, and to greater distances with guns of larger calibre.

Solid shots are now used only for piercing armour-plated ships and against strongly fortified positions. They are sharp-pointed steel projectiles of intense hardness.

The power of penetration of fragments of shell, or of the bullets contained in them, on living tissues, is not usually very great, or, at all events, is not long retained. Power of penetration of a small-arm bullet, as already explained, depends on its small diameter, its pointed shape, and its high velocity; fragments of shell and shrapnel bullets have characteristics quite the opposite of these, and

are consequently defective in penetrative power. Shell fragments are irregular, jagged pieces of metal, which offer, compared with their weights, extended surfaces to the resistance of the air; they therefore soon lose their velocity, while their shape is the worst possible for purposes of penetration. Shrapnel bullets are large and round, and the same statement is equally true of them.

A fragment of a common shell, consisting usually of a mass of metal with jagged sides and sharp angles, tears and lacerates the soft parts sometimes to an enormous extent; its velocity, as already mentioned, is usually low, consequently lodgment in the part struck frequently happens. In the same manner, though to a less extent, the bullets of shrapnel produce large entrance wounds and usually lodge in the soft parts. Although solid shot are, in modern times, as already mentioned, only used against ships and forts, yet it does occur that men are wounded by unexploded shells, and thus wounds similar to those produced by the old solid gunshot are the result. When a missile of this kind *at a high rate of velocity* strikes a part of the body directly, it carries all before it. When a portion of a limb is carried away in this manner, the end which remains presents a flat stump, nearly level, and much contused; the muscles on the face of the stump are crushed and lacerated, and do not retract; the interstices in the tissues are filled with effused blood; splinters of bone and bone-dust are found on the far side of the stump; "but the remainder of the shaft is not fissured or splintered."[1] If, on the other hand, the force and velocity of an unexploded shell have much diminished before striking, a portion of the body or of a limb may still be carried away, but the condition of the injured part is somewhat different: the amount of laceration of the softer tissues is greater; the skin and muscles are more irregularly torn, and shreds or ribbons of these tissues hang from the wound; the muscles are more separated from each other and show signs of having been partly dragged out from their sheaths and intermuscular septa; the face of the

[1] Longmore.

stump, if a limb be concerned, is more jagged and uneven; the bone splinters seen on the exit side are larger; "the remainder of the shaft is not so smoothly cut across, and fissuring and splintering occur in it to some extent."

Large fragments of common shell also produce extensively lacerated wounds, the edges of which are jagged and irregularly torn, but do not, as a rule, carry away a part of a limb; their velocity is usually low, their form is not the one best calculated to allow of deep penetration, and the injury is therefore great in area rather than in depth. Perhaps the most typical kind of wound produced by shell is that seen when a fragment has cut its way into the soft parts, and remains there, more or less buried; it is remarkable what huge masses of metal are occasionally hidden away in this manner. The entrance wound in the skin is nearly always smaller than the cavity in which the missile lies, and it is often difficult to account for the passage of so large a piece of metal through so small an aperture. The sides of such a cavity in a badly lacerated wound do not show much tendency to come together when the foreign body has been removed; the parts are so devitalised and torn by the force to which they have been subjected that they are incapable of resuming their original relations to each other, even when that which kept them apart has been removed. General or constitutional shock is a symptom which is usually well marked in cases of shell wound.

The wounds due to fragments of shell are, then, more often superficial than deep; they are always irregular, contused, and lacerated; and they are usually attended by considerable shock and the lodgment of the foreign body. This description of shell injuries applies more particularly to those produced by common shell; but similar wounds result from fragments of shrapnel when, although theoretically it is not intended to have this effect, the bursting charge ruptures the shell case. In general the wounds resulting from shrapnel bullets are of a less grave character than those from fragments of common shell or from rifle-bullets. Shrapnel bullets are spherical in shape in-

stead of ogival, and soon lose their velocity; their power of penetration and their destructive effects are therefore less.

When a part of a limb is carried away by an unexploded shell, or a severely lacerated wound is produced by a large fragment, although soon after the occurrence of the injury there may be no signs of contusion and ecchymosis of the surface immediately above, yet these will soon show themselves, and in a very marked degree: the condition of the parts after a day or two will be exactly as though they had been directly contused, and a knowledge of this fact will affect the question of primary amputation and the situation at which it should be performed.

The prognosis in cases of shell wound, however slight they may at first appear to be, should always be a guarded one; the recovery must always be slow; and the patient will have many risks to run, principally in consequence of the difficulty of keeping such injuries aseptic. All things being equal as regards the size and velocity of a missile, it is an admitted fact that shell fragments produce injuries of far greater gravity than bullets do. The contusion and laceration of the tissues quite prevent anything like union by first intention, and the chances of septic changes occurring in the vast lacerations made by fragments of shell are much increased by the probability of pieces of dirty clothing being carried in with them. The healing process in these cases must be by granulation—by, in fact, that process which modern surgical technique tries to prevent, and which is so often accompanied by fatal surgical infective disease.

Multiple Bullet Wounds from Single Bullets.—When speaking of the wounds of entrance and exit caused by bullets, I referred to them in such terms as might lead to the supposition that a small-arm projectile always makes either one or two apertures: a wound of entrance only if it lodged, and one of exit as well if it passed out. But this is by no means necessarily the case; for single bullets may make more than two openings and more than one track. This may occur both from bullets which have broken into two or more fragments on impact against bone,

and from bullets which have remained entire. A bullet which breaks up against a bone may make two or more tracks and two or more exit wounds. Sir Thomas Longmore mentions many cases of this kind: one of them in which a bullet entered the thigh of one side and split against the femur; the two pieces, passing on in different directions, caused two exit wounds in the thigh first hit and then two entrance wounds in the other thigh—five wounds from one bullet, two of exit and three of entrance.

This class of multiple wounds from single bullets was common enough when all small-arm projectiles were composed of soft lead; the modern hard-mantled bullet seldom, if ever, breaks against bone, and in future these injuries must be more exceptional. A bullet which remains entire may pass through the arm and the chest, or through an arm and a leg, if the limbs happen to be in a position suitable for this occurrence, in which case more than two wounds must necessarily result from the single projectile; and, in fact, injuries of this kind are not at all rare. On the other hand, a much more unusual occurrence is when there are a greater number of projectiles in a wounded man than there are wounds of entrance; and still rarer when, with a wound of exit, a bullet is yet lodged within the body. But both of these cases have occurred, the course of events being that in both cases more than one bullet passed in at the same entrance wound, and in the latter one of them failed to pass out.

"Wind Contusions," so-called.—A comparatively large number of severe, and even fatal, gunshot injuries are met with in warfare, in which, although all other signs of the gravity of the cases are evident at a glance, yet on careful examination no wound or contusion of the skin is to be seen. Formerly patients of this class were said to have been "struck by the wind of the shot," but this explanation is now known to be insufficient. In this kind of injury internal organs of the body have been ruptured, the muscles of a limb reduced to pulp, or the bones extensively comminuted, and yet the skin surface exhibited no sign of bruise or abrasion. Sir T. Longmore mentions some re-

markable instances of so-called "wind contusions": one which he saw in the Crimea in which the bones of the cranium were shattered, while the scalp remained entire. Another occurred during the Indian Mutiny, at Havelock's advance on the Alambagh: a gunner was lying out along his gun to rest himself, when a round shot glanced along his right thigh, passed across his abdomen and chest, and then smashed his left arm; his trousers were not torn, but several days afterwards, while the man was in hospital on account of the broken arm, a slough, many square inches in area, formed on the thigh, although on admission no injury of the skin at that situation had been visible. In the Crimea a captain of the 42nd Highlanders was struck across the abdomen by a fragment of shell 22 lbs. in weight; no bruise or discoloration of the skin was to be seen, but this officer died almost immediately of internal hæmorrhage.

This is the class of injury to which the term "wind contusion" has been applied; and in most campaigns instances have occurred in which men have been so injured —cases in which the bones of the limbs and even of the skull, and the organs in the abdomen, both hollow and solid, have been so severely damaged as to cause fatal effects, yet on careful examination no contusion or abrasion of the skin over the injured parts had been produced. Surgeons formerly considered that these injuries must be the result of "violent percussions" of the air by the shot as it passed close to the man's body—in other words, of the "wind of the shot." It was also suggested that the rush of the shot created a vacuum, and that the sudden inrush of air to fill it might be the cause of "wind contusion" when this occurred close to the body of the person injured. A naval surgeon suggested that they were the results of pieces of canvas, ropeyarn, and other light articles such as are common on board ship, being carried along by the shot and striking the part injured.

But the question of the causation of the so-called wind contusions hardly requires discussion in these days. So many cases of shots passing as close as possible to men

without absolute contact, in which wind contusions were not produced, are now on record, that it is evident that the "wind theory" does not explain the condition of things referred to. These injuries are always the result of solid shot, unexploded shells or grape, or of large fragments of shell; and Sir Thomas Longmore observes: "The true explanation of the phenomena seen in cases of wind contusion is to be found in the peculiar direction, and especially in the degree of obliquity, with which the missile has happened to impinge against the elastic skin, together with the relative situations of the internal organs or bones injured in regard to this missile and to other hard substances on the opposite side to the part struck." Thus it is conceivable that the skin of the abdomen may be just grazed by a solid shot, or by the smooth surface of a large fragment of shell, in so oblique a direction that the skin itself may not be torn, while the internal organs may be extensively ruptured; or the bones of a limb may be shattered during a similar occurrence by being compressed between the shot and some hard substance against which they were resting. The elasticity of the skin enables it to yield to the pressure, while the more resisting matter within is smashed. "Baron Larrey, who examined many fatal cases of this kind, which others were inclined to attribute to the 'wind of the shot,' has related that he always found so much internal disorganisation as to leave no doubt on his own mind as to its being the result of pressure by the projectile."[1] The indirectness of the blow, and the distensibility and toughness of the skin, are the marked and constant conditions of these cases, and are sufficient explanation for the severe injuries to the deeper parts while the skin itself remains entire and untorn.

Poisonous Effects of Projectiles.—From almost the earliest days of the use of leaden bullets, the opinion has been held by many surgeons that these projectiles contained substances which produced the effects of poisons in the wounds made by them. Ambrose Paré, Gale, Wiseman, Velpeau, and others strongly opposed this view, and

[1] Longmore.

insisted, as we do now, that it was unnecessary to presuppose poisonous matters in the lead in order to account for the appearances seen in bullet tracks and for the evil course these injuries so often ran. Until comparatively recent years it might be said of all bullet wounds that suppuration was sure to accompany the healing process. It was from this circumstance, and from the great general constitutional disturbance which preceded it, that this opinion originated. The dark appearance and the sloughing condition, together with the septicæmia which so frequently resulted from bullet wounds in former days, were really due to the complete absence of even fair hygienic surroundings, and to a septic process thus engendered in them. But the septic matter was not one mixed with the metal of the bullets and deposited in the wounds, but an organic poison developed in the tissues themselves by a fermentation process initiated and carried on by micro-organisms derived mostly from "surgically unclean" hands and instruments, and the natural chemical result of the changes always so produced in living tissues.

The means taken by surgeons in Paré's time, and for long afterwards, to remove the poison and its effects, were to apply boiling oil to the wounds, to apply suction by means of cupping-glasses, and to enlarge the track by incisions so as to give free exit to discharges. The belief was slow in dying, but it did die, although even as late as 1870 the Germans complained that the bullets of the French mitrailleuses contained poisonous substances in the lead.

Burning Effects of Bullets.—The theory that the tissues are burned by the bullet is also a very old one. It was supposed that a projectile acquired so much heat from the ignition of the powder, and from friction against the barrel and against the air in its flight, that it charred the surface of the wound it inflicted. Ascribing the production of the heat to another cause, modern surgeons have revived this notion, arguing from Tyndall's law that "arrested or impeded motion is converted into heat." Hagenbach and Socin, in Switzerland, and Malhauser, in Ger-

many, have reintroduced this subject. Dr. Hagenbach asserts that his experiments prove that when a conical leaden bullet is fired from a distance of 100 metres with a velocity of 320 metres at an iron target, it is melted to a considerable extent on striking. "Professor Busch, of Bonn, has expressed his belief that rifle-bullets, on striking bone, actually become melted and divided into numerous slug-like particles, and that this adds greatly to their destructive effect in wounds." [1] Longmore sums up a full discussion of this subject by saying: "Practical experience, indeed, contradicts the notion of the surfaces of a wound being scorched by heat, whether the projectile has completely traversed the tissues concerned, or its passage has been arrested in the flesh or by the opposition of a bone." He adds: "I have seen a large number of bullets that have been arrested in their flight by collision with bone, but none that I have ever examined have given me the impression that their changed condition was due to melting." Delorme also opposes the view that bullets can acquire such an amount of heat as would affect the tissues through which they pass or in which they lodge.

No doubt, when a projectile is driven at high velocity against an iron target or other object which suddenly extinguishes its energy, that energy of motion must, in accordance with the law of the "conservation of energy," be converted into some other kind of force—heat in this case. But when a bullet traverses a man's body or his limb, even when meeting bone in its passage, if it is travelling at a high rate of velocity it passes completely through the part, losing some of its energy, no doubt; but the energy lost by the bullet is not converted into heat but into other motion, for it tears up the soft tissues and breaks the bone into fragments, driving them apart in all directions, and it passes onwards carrying much of its energy with it. Or, on the other hand, if the bullet lodges in the part struck, that fact itself proves that its energy at the moment of impact was comparatively small, for it had only sufficient to enable it to penetrate, and it lost it all in doing so and not

[1] Longmore.

in developing other kinds of energy. Bullets discharged against iron targets, no doubt, do develop enormous heat, probably to the extent of fusion; but the conditions when bullets traverse animal tissue are so different that a like result certainly does not take place.

CHAPTER III.

ON THE PRIMARY PHENOMENA AND SYMPTOMS ACCOMPANYING GUNSHOT WOUNDS.

THE primary symptoms which are perceived immediately on the receipt of a gunshot wound are Pain, Hæmorrhage, and Shock, the sequence of their occurrence being probably in that order.

Pain, of more or less intensity, is seldom absent as an immediate symptom of gunshot injury. But while this is certainly true of the great majority of cases, numerous instances are authentically recorded in which men were unaware that they had been wounded until attention had been drawn to their condition in some secondary manner, such as a feeling of faintness, the observation of the blood either by the man himself or by one of his comrades, inability to move the injured limb, &c. The quality of the primary pain varies in different individuals; it varies also with the state of excitement the man may be in, and with the earnestness with which he may be attending to the business in hand. Under the stimulus of the excitement caused by the din of battle, a man may receive a wound without for the moment being aware of the fact.

Under ordinary conditions the intensity of the pain depends on the situation of the wound and on its gravity and extent. The pain of rifle-bullet wounds, when bone is not implicated, is often not very severe, and has been described as like that of a smart blow with a cane, or the sudden passage of a red-hot wire through the tissues. Sometimes, however, it is intense, owing probably to interference with nerve filaments. Lacerated wounds, the result of fragments of shell, usually cause severe pain for some time; later the surfaces of such wounds become numbed in consequence of the extent and severity of the contusion they

have suffered, and the pain lessens or disappears, to return again when reaction and recovery begin to set in.

The pain of a gunshot wound when bone has been traversed by the projectile, and fracture and comminution have been produced, is often very intense; but its duration is often short, either from loss of consciousness or numbing of the parts coming to the relief of the sufferer. Pain is sometimes so severe as to threaten life, but this is quite exceptional; and, be it great or little, it is not a symptom from which any accurate estimate of the gravity or otherwise of the injury can be formed. When large nerves are implicated it usually happens that the most severe pain is referred to some part remote from the site of the injury. Longmore, in this country, and Weir Mitchell, in America have recorded cases in which the patients referred the sensation of pain to the uninjured limb. Pain at the exit is nearly always of greater severity than that felt at the entrance side, and, when bone is not struck, it is referred rather to the situations of the skin wounds than to the track of the missile through the soft tissues. As a rule, pain of great intensity and of any considerable duration is not common in gunshot wounds, and, when present, it is usually the result of interference with large nerve-trunks.

Local Shock and Anæsthesia.—On the other hand there is often a local deadening of sensation in the part struck and its immediate vicinity in gunshot wounds. The surface and track of the wound, and the parts around, are insensible to touch or movement; pain is not felt in the lacerated part; a sensation of numbness is the only one remaining in it. This condition of local anæsthesia is most marked from bullets at short ranges at high rates of velocity, and Fischer, a German surgeon, has pointed out that it is most evident on the entrance side. Its onset is rapid, and its duration variable, from a few hours to a day. Wounds affected by this traumatic anæsthesia are apt to give rise to septic discharges. Probably in these cases the vitality of the parts is so lowered that the tissues fall an easy prey to pyogenic micro-organisms, their power of resistance

being interfered with. On this account, wounds so affected require special care in their treatment to render them aseptic by thorough washing with warm antiseptic solutions, and to keep them so by the use of dry and absorbent wool dressings.

General or Constitutional Shock.—Constitutional shock is a train of symptoms common to all injuries, but especially marked in gunshot wounds. It is that peculiar condition of prostration or collapse which supervenes almost immediately on the receipt of and injury, and which is characterised by feebleness and fluttering of the pulse and rapidity of the heart's action, lowering of the temperature, pallor of the face and of the surface generally, and tremors of the limbs, but not necessarily accompanied by loss of consciousness; the breathing is, for the most part, shallow, but interrupted at intervals by deep, sighing respirations; the body feels cold to the touch, and is covered with perspiration; there is great nervous depression, and this is evidenced by the expression of the face, and by the signs of mental disturbance as shown by incoherence of speech and thought; nausea and vomiting are common symptoms.

Shock is usually most marked in penetrating wounds of the abdomen, in all extensive wounds attended by crushing and smashing of bone, and in cases of severe wounds and contusions caused by large projectiles or their fragments. The degree of shock varies, as a rule, with the severity of the injury producing it; but this is modified by different circumstances, such as the temperament of the injured person, and his condition of excitement or otherwise at the moment of being wounded. Nervous susceptibility, too, has a good deal to do with the development of shock, some men showing the symptoms in a marked degree in consequence of a slight injury, while, in others, severe injuries produce little or none of the condition under consideration. The velocity of the projectile also influences the degree of shock following a gunshot wound. Bullets at high rates of velocity are followed by more severe symptoms than when their velocity is low; but this is probably due to the fact that their destructive effect on

the tissues is correspondingly great—that, in fact, the wounds are more extensive. Intense pain accompanying a wound is a cause of increased shock, but mental as well as physical conditions have influence in determining its intensity. The impression in a man's mind that his wound will prove fatal acts in this way. But generally the symptoms of shock are more or less marked as the injury is of greater or less gravity.

In some instances shock may be so extreme that it becomes the direct cause of death, and this is especially likely to be the case in shell injuries and in penetrating wounds of the abdomen, irrespective of the quantity of blood lost. Longmore records that out of 100 consecutive fatal cases in the Crimea, shock was the direct cause of death in 22; "out of the 22 deaths only 8 were caused by bullets, and in all of these the cavity of the abdomen had been penetrated by the projectile. In the remainder the injuries were caused by gunshot, shell, or grape." There is much evidence to show that shock is not observed in so marked a degree after simple wounds of the soft parts produced by the modern small-bore bullet as was formerly the case in similar injuries from the larger projectiles.

As a rule the severity of shock following wounds of the lower extremity is greater than that seen in cases of wounds of the upper extremity, and the nearer the site of the injury is to the trunk the more pronounced the signs of this condition are likely to be.

This state of commotion or shock is liable to be mistaken for syncope, concussion of the brain, or for the anæmia following acute hæmorrhage. Syncope is, however, more rapid in its onset and departure; it is attended by complete loss of consciousness, and by the almost complete absence of the pulse. Moreover, it is usually consequent upon intense pain or great loss of blood; whereas shock may be quite independent of these conditions. If both be present together, it is difficult to differentiate the symptoms.

Symptoms of Shock.—The symptoms of shock from injury are those of intense nervous depression: the face is pallid, the eyes fixed, the pupils dilated; the features are

shrunken, and the expression is one of anxiety or even of fright; the body and face are covered with a cold sweat; the respiration is jerky and sighing; the heart's impulse is weak, rapid, and perhaps intermittent; the pulse small, soft, irregular, and frequently dicrotic. Frequently vomiting, and sometimes incontinence of urine and fæces occur; occasionally retention may be present. The temperature is lowered one or two degrees, or even more in very severe cases, and the wound does not bleed. Although the patient may be sensible, examination of the wound at this time elicits no manifestations of suffering on his part; but rigors, tremblings of the limbs, and chattering of the teeth may result from such procedures. M. Harald Schwartz, a French army surgeon, states "that the appearances of shock were, in his own experience, so characteristic that by them alone he was able to recognise the cases of severe bone injury without actual examination of the wounded;" and he adds that "in moments of overcrowding in field-hospitals he was able, by inspection of the face alone, to separate the cases requiring immediate assistance from those who might be moved without further examination."[1] M. Redard, another French surgeon, who has paid great attention to the state of shock following on severe gunshot injuries, states that "wounded whose temperatures fall below 36° C. (96.8 F.) usually die." The same authority remarks that "all wounded men who do not recover their temperatures in about four hours, or in whom reaction is not in proportion to the depression, should be considered as seriously injured and unfit to undergo operation. The thermometer is an unfailing indication as to when operative interference may be permissible."

The presence of shock to any considerable extent is a contra-indication to operative measures, except those of imperative necessity, such as the ligature of exposed vessels, the immobilisation of fractured limbs in order to prevent further damages, &c., &c. Delorme remarks that "men subjected to operation while in this condition do not recover from it: they remain in it and die."

[1] Delorme, vol. i.

The Treatment of Shock consists in the application of warmth to the surface, and the administration of stimulants internally. The man should be placed in the recumbent position; hot bottles or hot bricks should be applied to the limbs and body; he should be covered with warm blankets, and friction used to the surface. Stimulants, such as hot wine or spirits and water, should be given, and stimulant enemata used. The injection of ether, to which, if the collapse be not very profound, a few drops of tincture of opium have been added, has a most beneficial effect; but in this connection it is well to point out that opium in any form or quantity must be employed with the greatest caution, if at all, in the treatment of cases of extreme shock or collapse.[1] The transfusion of saline solutions in cases of deep and prolonged shock has been recommended; but Mr. Watson Cheyne[2] suggests that "probably as much good will be done by injecting two or three pints of saline solution into the rectum as by their direct transfusion."

Primary Hæmorrhage in Gunshot Cases.—The amount of blood lost in the primary hæmorrhage consequent on a gunshot wound depends to a great extent on the kind of missile which causes the injury. The primary hæmorrhage following on wounds produced by unexploded shell, large shell fragments, or balls from case-shot, is usually not of great severity, and it seldom proceeds to an extent sufficient to cause death on the field. Even when portions of limbs are carried away, as they may be by some projectiles of this class, the hæmorrhage is in most cases slight, considering the extent of the wound. Wounds caused by shell and shell fragments are always of the lacerated and contused types; the vessels severed in them are lacerated also, not clean-cut, and on this account are but little likely to bleed for any length of time. Vessels exposed on the surface of a lacerated wound, or on the face of a stump when a limb is carried away by a large projectile, are more or less dragged from their sheaths, and hang loosely on

[1] I have a vivid recollection of two cases of this kind where the use of morphine subcutaneously very nearly ended in the deaths of the patients.

[2] Treves' "System of Surgery," vol. i.

the torn tissues; under these circumstances they are in the best condition to undergo nature's hæmostatic process, the retraction of the inner and middle coats and the closure of their orifices by clots. Fatal hæmorrhage in this class of case, therefore, comparatively seldom occurs.

Primary hæmorrhage from wounds by small-arm projectiles in general is likely to be seen in direct proportion as the diameter of the bullet is small and its velocity great. When the large leaden bullets were in use, it frequently happened that large arteries escaped injury even when the anatomical position of the wound was such that the vessels appeared to be in the direct track of the missile. The slow-travelling, blunt-pointed bullet was occasionally able to push aside a large vessel without making an opening into it. Sir Thomas Longmore refers to many curious and interesting cases of the escape of blood-vessels from injury by smooth-bore bullets, in the second edition of his work. On the other hand, when a vessel was hit fairly by the large projectile, the great size of the bullet rendered it more likely to cut the vessel completely across, and this condition, as we know, always tends to lessen hæmorrhage from an artery. Besides, when a blunt projectile at a low rate of velocity divides an artery, the cut ends of the vessel are contused and lacerated, not clean-cut, and this condition tends to lessen bleeding.

The modern small-bore is certain to cause more profuse primary hæmorrhage, and to lead to more deaths on the battle-field from this cause before assistance can reach the wounded, than the older bullet did. The extreme velocity at which these projectiles move, their small diameters, and their pointed form, are conditions which greatly influence the characters of the apertures they produce in blood-vessels, and of the kinds of sections they make of them. Arteries which lie in their track are certain to be injured; their great velocity enables them to cut holes in the sides of the vessels when they strike them tangentially; and their small diameter renders it possible or them to make clean-pierced wounds through vessels of even less diameter than their own, leaving shreds of the outer coats remaining

in the continuity of the tube to prevent retraction of the cut extremities. Wounds of these kinds are those which are most calculated to give rise to serious and fatal primary hæmorrhages.

No really accurate and reliable estimate of the proportion of deaths which take place on the field after a battle from primary hæmorrhage, has ever been made. The business of those who attend on a battle-field when the fight is done, whose knowledge would enable them to judge of the different primary causes of death, is with the living, not with the dead, and their time is so fully occupied with their duties to the wounded that they have none to spare for making observations on the dead.

Longmore says that "there is no doubt about the fact that primary hæmorrhage from gunshot wounds does not often come within the observation of army surgeons," and that "only 0.3 per cent. of such cases were registered in the returns of the British army in the Crimea, and 0.05 per cent. in the returns of the American War." He quotes M. Baudens as saying that "he had often found, by examination of the dead lying on fields of battle, that death had been due to primary hæmorrhage." Otis states, in his history of "The War of the Rebellion," that "it is probable that a large percentage of the killed in battle were cases of primary hæmorrhage," and he quotes Surgeon J. A. Lidell, who was convinced, from his own observation, that "a large proportion of persons killed in battle perish directly from loss of blood."

Even the most emphatic of these statements does not at all convey an adequate idea of the importance of primary hæmorrhage as a cause of death on a battle-field. It is much nearer the true state of the case to say that the great majority of those who die before succour can reach them succumb from primary hæmorrhage. In a few, very exceptional, cases, general or constitutional shock may, from the extent and gravity of the injury, cause death within a few hours, quite apart from loss of blood; wounds of the brain and of the higher regions of the spinal cord may prove fatal instantaneously or within a few minutes,

in consequence solely of the interruption of functions dependent on the integrity of these vital parts. But if we exclude these causes of rapid or immediate death, all other fatalities on the field are due to primary hæmorrhage. Wound of the lung is not a cause of rapid death unless the large blood-vessels at the root of the organ be implicated; wound of the heart is immediately fatal from primary hæmorrhage; wound of the abdomen and of its contents is only rapidly fatal when large vessels are severed, and this statement is equally true of wounds of the extremities. It is probably understating the case to put the ratio of deaths on the field due to hæmorrhage at 85 per cent. of the total dead.

CHAPTER IV

THE TREATMENT OF WOUNDS IN WAR

General Remarks.—From the earliest times of which we have records of the methods of surgical treatment of wounds and injuries received in warfare until the Russo-Turkish Campaign of 1877–78, probably the most commonly used local application for these cases was "water-dressing"—lint wet with water or with water and alcohol. Ointments, balsams, astringents, of almost every kind, and poultices were also employed. Suppuration and profuse discharges were the almost necessary consequences of these methods, and the older surgeons were led to practise *débridement*—the making of incisions at the skin openings—in order to convert the narrow apertures into open wounds, and so give exit to the products of the inflammatory processes, which were then considered to be the natural and inevitable result of all healing action.

Surgical infective diseases of all sorts have always been the scourges of war hospitals, and even in the Franco-German War of 1870–71 but little was done for their prevention by the use of antiseptics and by the modern methods of the local treatment of wounds. The employment of such local applications as those above referred to was the prolific cause of septicæmia, pyæmia, hospital gangrene, and in fact of all the constitutonal septic conditions so frequently seen in war hospitals as complications following on wounds, and as the causes of enormous death-rates amongst the wounded in campaigns.

During the American War of the Rebellion, water-dressings were generally used. In the war of 1870–71, the French used ointments spread on lint, dry lint, and, to a small extent, water-dressings, with the usual result, the production of septic wounds; while the Germans made

some attempts at antiseptic treatment, and with more satisfactory results. Although the antiseptic treatment of wounds in civil practice was written about and tried soon after 1860, the earlier methods employed in Listerism were considered to be so complicated, and the technique required so large an expenditure of time, that no effort was made to apply it in war until the occurrence of the Russo-Turkish Campaign of 1877–78. Even in this war, when the first serious attempts at modern treatment of the wounded were made, in the French Expedition to Tonquin, in the English Campaign in Egypt, during times when antiseptic methods were still but little known by army surgeons, and while they were still complicated and difficult of application in war time, the results achieved in the matter of the avoidance of surgical infective disease, and of demonstrating the superiority of Listerism over all other means of treatment, were unprecedented, almost unexpected.

General Treatment of Wounds.—The changes which had taken place in the treatment of gunshot wounds from the early days of Paré up to the time of the Franco-German War, and all the efforts which had ever been made to discover the most suitable local application for these injuries, had been made with the object of preventing the occurrence of septicæmia, hospital gangrene, and suchlike fatal forms of disease which had always followed in the wake of an army in the field. But no glimmer of the real causes of these complications had been perceived by surgeons, and little or no good result had rewarded their efforts at combating them until the methods of Lord Lister, based on the experiments and teaching of Pasteur, began to be taken up by army surgeons, even in a limited and modified way, in the Russo-Turkish War of 1877, and by the Germans in the war of 1870.

If Lister had done nothing more for surgery than teaching the surgeon the necessity and importance of avoiding contamination of the wound he treats, and pointing out that the means of doing this was to asepticise his hands and instruments before applying them to open wounds, he

had done well for the science of surgery; he had, indeed, done more for the general treatment of wounds than any of the great men who had been his predecessors had achieved. But he has done much more than this: he has revolutionised the whole science of surgery and made modern surgery possible. Yet, while we may stand amazed at the advances surgery has made of late years under his teaching, we probably hardly suspect the possibilities of the future. In no branch of surgery, abdominal and brain surgery not excepted, has antiseptic treatment brought forth more marvellous changes for the better than in the treatment of wounds in war.

Contrary to what was believed in the early days of Listerism, we now know that contamination of wounds is much more likely to occur from contact with dirty, that is "surgically dirty," hands and instruments than from the admission of air to them. The A B C of Listerism, as now practised, consists in carefully avoiding placing in wounds those micro-organisms which are admitted to be the sole causes of suppuration and fever, and then in preventing their access by means of the dressings we employ. If we ourselves place no microbes in wounds, and if we apply to them dressings which contain none, and which are in themselves perfect mechanical filters for them, we shall have done much for our patients towards saving them from surgical infective diseases and allowing the ever-ready processes of natural repair to effect a cure.

Formerly it was considered the natural order of things that wounds which did not heal by direct union should do so by granulation and suppuration, and the stage of suppuration was actually hoped for, because the production of what was called "laudable pus" was looked upon as a salutary and necessary process. But, between the failure of union by first intention and the setting up of suppuration, the wound passed through a stage of inflammation, as shown by the usual signs of that condition, accompanied by more or less constitutional disturbance or "surgical fever," which were considered to be the unavoidable and natural concomitants of repair. The relief from this sur-

gical fever was always preceded by a discharge of healthy pus from the surfaces of the wound, and this apparent relation of cause and effect led to a line of treatment calculated to encourage suppuration, such as covering the wounds with water-dressings and poultices of various kinds. We know now that this suppuration and fever are brought about by the infection of the wound from without by pyogenic bacteria, and that natural though this may be under poultices and water-dressings, inasmuch as the causes of this infection abound in nature, and as poultices and water-dressings are perfect hot-beds for the multiplication of bacteria, yet, if we can guard the wound from the advent of this foreign matter, not only will it heal without any suppuration, but our patient will have neither surgical fever, nor pain, nor inconvenience of any kind beyond that inseparable from the mere existence of the wound itself.

The fact that this infective matter does reach the wound from without is of vast importance to the surgeon: the whole theory and practice of Listerism and aseptic treatment has for its basis the truth of this proposition. Regarding the access of microbes from without, Rosenbach writes: "From experimental work I have been led to propound this view, that every suppurative phlegmon occurring in connection with wounds, and, indeed, every inflammation in wounds passing beyond the degree necessary for repair, is caused by micro-organisms which have penetrated from without." And Mr. Stanley Boyd, writing on septicæmia and pyæmia, says: "We may conclude, therefore, that organisms found in a putrid wound have entered it from without; and this is of fundamental importance in surgery. For if organisms could enter a wound from the sides of the tissues, aseptic treatment would be impossible. As it is, we are sure that if we allow no loophole for the entry of germs from without, our wounds will remain free from ferment processes, and our patients thus be saved from the dangers of septic intoxication, from septic infection, pyæmia, and all surgical infective diseases."

Any very detailed or minute examination into the subject of surgical bacteriology would be out of place in a

work of this kind. It is fully entered into by Dr. Sims Woodhead in Mr. Treves' "System of Surgery" (1895), in the "Proceedings of the New Sydenham Society," 1890, and in numerous other works. It may, however, be well to sum up in a few words our present knowledge of the subject.

The origin of the infective matter above referred to, we now know to consist of living vegetable organisms, classed under the general terms bacteria or germs. The two most important divisions of bacteria, from a surgical point of view, are micrococci and bacilli. Both these kinds of micro-organisms, when present in wounds, are capable of producing most fatal forms of septic disease either by the formation of toxines, which are absorbed into the general system, or by circulating in the blood-stream and causing septic emboli, which are arrested when they arrive at arterioles or capillaries too small to allow them passage, thus producing infarcts and pyæmic abscesses. The pyogenic micrococci are responsible for all suppuration which occurs in wounds, and for all septic surgical disease which results from this process; and the most important of these micrococci are the Staphylococci and the Streptococci of various kinds.

Some kinds of bacteria, as already mentioned, are taken up by the blood, and produce their ill effects in parts of the body more or less distant from the wound through which they gained access. Others are strictly localised at the wound, where they grow and multiply, breaking up the chemical constitution of the tissues by a process of putrefaction or fermentation, and producing by this action new chemical compounds known as toxines. The absorption of bacterial toxines in the latter case produces a sapræmia or true septic intoxication of the system, the poisons only, not the micro-organisms themselves, entering the system. When these are absorbed in large quantity they may rapidly cause death; but when the absorption is of smaller quantity, or when it is extended over a longer time, a febrile hectic condition is produced which is called septic or traumatic fever, a condition always seen accompanying wounds which are not aseptic.

The pathogenic bacteria also probably produce toxines; but, besides this, they spread and multiply within the body, producing a septicæmia, and pyæmia with local manifestations in the form of abscesses, effusions into joints, &c. Of these, the non-specific or merely pyogenic micro-organisms are those which mostly interest us in relation to surgery; because to them are due those sequelæ which, for the most part, render those wounds which are not immediately fatal dangerous to life by causing suppuration, septicæmia, cellulitis, osteomyelitis, and hospital gangrene—in fact, all surgical infective disease, the avoidance of which is the desired end and aim of antiseptic and aseptic surgery.

The cells of the living tissues are themselves capable, without outside aid, of dealing with and destroying a certain quantity of bacterial poison; the dose is, in fact, of importance in determining whether or not the consequences of infection shall be severe or mild. If the amount be such as the tissue cells can account for, then the deleterious effects are slight or not apparent; if greater than this, then surgical infective disease of one kind or another is produced, and its severity is directly proportional to the amount absorbed. That bacteria are present in a wound under conditions suitable for their propagation is not of itself a guarantee that they can produce their deleterious effects; they must be there in sufficient numbers, and of such a virulent nature, that the resisting influences of the cells are overcome and that they can gain a sure foothold. Watson Cheyne has shown that it required 18 millions of the Proteus vulgaris to produce any appreciable effect whatever, and that it requires 250 millions to produce an abscess; that while 1000 millions of the Staphylococcus aureus were required to kill an animal, 250 millions produced only a small local abscess.

Virulence of Bacteria.—Micro-organisms, even of the same species, vary considerably in virulence. The conditions under which they have grown, as regards temperature, sunlight, air, &c., modify them in this respect. Some bacteria have their virulence attenuated by their passage

through animals, while in others it is intensified. Pyogenic cocci are always present on the skin and in clothing, but their power of infecting wounds is much less than that possessed by similar organisms to be obtained in hospitals in which surgical cases are being treated and where septic diseases have occurred. This is probably the explanation of the observed fact that septicæmia and hospital gangrene have been more rife and of a more virulent type during the later periods of campaigns than in the earlier ones. As the wounded increase in numbers and are aggregated into buildings, so, in the absence of very strict antiseptic treatment, septic disease has become more common. The possibly low degree of virulence in the micro-organisms almost certainly present in shreds of clothing so frequently driven into bullet wounds must be explanatory of the cases in which gunshot injuries, so complicated, heal without suppuration.

Besides the quantity and quality of the infective matter which contaminates a wound, certain conditions of the patient and of his surroundings, and of the wound itself, have a marked influence on the ultimate results of such infection. Any condition which tends to lower the general health and vitality of the patient tends to lower the vitality of the living cells at the site of the wound, and therefore to lessen their power of opposition to the action of bacteria. Fatigue, exposure, bad or insufficient food, bad hygienic conditions, have this effect, and render wounded men more prone to infective disease. As regards the state of the wounds, any local cause which lowers the vitality of the surrounding tissues leaves them an easier prey to bacteria. Cells, to make the best fight against the invading micro-organisms, require to be in their most active condition; otherwise they soon cease to resist, and the enemy gains a sure foothold. Thus it is that wounds which are accompanied by contusion and laceration, as well as those made by operating with blunt knives, are more liable to permit of general infection of the system.

Again, since bacteria derive the food necessary for their existence from the proteids or the carbohydrates, the salts,

and other matters contained in the liquids and juices of the tissues, it follows that the drier a wound is kept, the more care the surgeon devotes to stanching hæmorrhage, even to the slightest ooze, and to preventing accumulations of serum and other fluids within its recesses by means of drainage, the less likely will it be to suffer invasion by micro-organisms, or, if invaded, to support them for long in a condition likely to be harmful to the patient. Time spent in ensuring the dryness of a wound before closing it, by careful attention to bleeding points, is therefore not time lost; and for the same reasons, when a cavity exists, or where it is probable that oozing of blood or serum may occur, a drain should be placed. The great object, too, besides preventing the access of bacteria, of dressing wounds with dry and absorbent wools and similar materials, is that, through their affinity for fluids, they may abstract effused discharges of all kinds from them, and so deprive the infective germs of the food on which they thrive and multiply.

This is but a meagre summary of the bacteriology of wounds; but it is of great importance that army surgeons should have as full a knowledge of, and be as thorough believers in, the theories which Pasteur propounded, and the methods of treatment which Lord Lister teaches, as are our colleagues in civil life. Antiseptic treatment may be more difficult in warfare than in civil practice, but not on that account should it be neglected. The scourge of all war hospitals has always been surgical infective disease. Something has been done already towards diminishing its ravages; but it is for the future to show how our improved knowledge and our more scientific methods may be best employed towards controlling these fatal forms of wound complication, and towards preventing them from assuming such proportions as have hitherto obtained.

I may mention the following contrast, though I do not offer it as an argument in favour of aseptic surgery—the advantages of modern scientific surgery need no proofs in these days—but merely as an instance of the different results obtained in war hospitals by it and by the older meth-

ods. In the Russo-Turkish War of 1877-78 Carl Reyher and Von Bergmann treated their cases as far as possible aseptically: Reyher records "18 primary aseptic cases of bullet wound of the knee-joint, of which 15 recovered with movable joints and 3 died;" Bergmann gives "15 cases of compound fracture of the knee-joint (excluding mere capsular wounds), of which 14 recovered (2 after amputation) and only 1 died (also after amputation)."[1] Whereas "Hennen, Larrey, and Guthrie, who, of course, used only the methods known in their times, all agreed that gunshot wounds of the knee-joint demand amputation, as the result otherwise is fatal; and Longmore tells us that in the Crimea not a single man wounded in the knee-joint recovered without amputation." MacCormac himself, from whose later writings the above statements are quotations, held similar views in 1871, after the Franco-German War.[2]

Sword and Bayonet Wounds.—The comparative infrequency of this class of injury in war has been already referred to.

The left side of the body being more exposed, sword wounds are, in the majority of cases, found to be inflicted on the left side of the head and neck, and on the left upper extremity. As a rule they are not of great severity, nor do they cause much immediate danger of life, especially when produced by the European weapon, unless they are accompanied by fracture of the skull or implication of large vessels. Contusion always, and laceration sometimes, of the edges of these wounds are observed in European warfare, in consequence of the bluntness of the swords and sabres employed in Western countries; while sword wounds resulting from the use of the common Asiatic sword, or knife, are as clean-cut as incisions made with the surgeon's catlin, than which it is hardly less keen. Occasionally, however, even the European sword, when wielded with great force, especially by a cavalry soldier, and when the momentum of the horse is added to the strength of the

[1] "Antiseptic Surgery," by W. Watson Cheyne.

[2] "Notes and Recollections of an Ambulance Surgeon," by Wm. MacCormac.

man's arm, will slice away large portions of the soft parts and fracture bones.

The Prognosis and the gravity of sword wounds depend more upon their depth and upon whether or not they are complicated by injury to large vessels and nerves and fracture of bone than upon their linear extent. Simple incised wounds, not so complicated, should follow a favourable course and heal rapidly and well. When long bones or the bones of the skull are fractured, the prognosis must, of course, vary with the severity of these additional injuries.

The Treatment to be carried out in these cases will be in accordance with the usual principles of general surgery. Bleeding vessels must be sought for and both ends ligatured; tendons and important nerve branches which may have been severed must be brought together with thin silk or catgut; foreign bodies, pieces of clothing or accoutrements, if any, must be removed; the wound and the skin in its vicinity should be thoroughly asepticised, and, when all bleeding has ceased, its sides and skin edges brought together by sutures, a continuous horse-hair suture being the best for accurate approximation of the incision in the skin. Dry and absorbent dressings under a bandage which exerts a firm pressure, and, if the wound be so placed as to admit of it, a splint to keep the part at rest, should be applied. If this mode of treatment be so well crried out as to avoid septic contamination and to ensure thorough disinfection, simple sword and sabre wounds, no matter what their length, should heal under their first dressings, any necessity for the removal of which, before complete cure has taken place, will, with almost absolute certainty, be indicated by the thermometer. If the temperature remain low, and the wound fairly comfortable and free from pain, or excessive pain, the first dressings should not be renewed for eight or ten days. If fracture of bone complicate the injury, the bone must be put into good position, and treatment on the lines above detailed should convert the case into one of simple fracture.

Punctured Wounds from bayonets are less likely to heal

rapidly and without trouble than are those just referred to. The tissues in their tracks are subjected to considerable laceration and contusion, in consequence of the shape of the weapon and of its gradual increase in thickness from the point, these conditions being naturally against a process of union by first intention. Complete penetration of a limb or of the body is not infrequent in bayonet injuries, and the gravity of these cases depends on the depth and extent of the penetration, as well as, in a large measure, on the characters of the structures traversed. Large vessels and nerves may be wounded; and in the former case the shape of the wound necessarily made by a bayonet—a puncture—is precisely that best calculated to give rise to prolonged hæmorrhage. Bleeding from this cause is prone to result in the formation of a traumatic aneurism. In consequence of the blood being unable to escape outwards from want of apposition in the apertures made in the different layers of structures it becomes pent up in the depths of the wound and effused through the tissues, thus constituting a true traumatic aneurism. A bone, too, may be fractured or split from a bayonet being thrust into it, as the driving force with which it is used is very considerable, supplemented as the muscular effort of the man using it is by the weight of the rifle.

The Treatment of Punctured Wounds, whether they are produced by the bayonet, lance, spear, or by sword thrusts, requires especial care in ensuring an aseptic condition. It has hitherto been observed that wounds of this class have been peculiarly liable to take on an unhealthy and suppurative action; but, now, attention to thorough surgical cleanliness in such cases by the usual means should succeed, in them as in others, in preventing this complication. If hæmorrhage be taking place, as evidenced either by the outward flow, or by the rapid swelling of the part from accumulation of blood effused within the tissues, and the formation of a traumatic aneurism, the skin opening must be enlarged and the vessel secured above and below the puncture in its walls; the clots must be turned out, and irrigation with hot 1–4000 sublimate solution per-

formed. To prevent the suppuration which formerly so often complicated these wounds, reliance must be placed on careful attention to antiseptic measures, and, above all, to irrigation of their tracks.

When it has been necessary to enlarge the skin openings in order to ligature arteries or to examine fractured bones, irrigation will be a simple proceeding; but where this has not been done, irrigation to the bottom of the wound may be difficult in consequence of a want of coincidence in the apertures in the several layers of tissues traversed by the weapon. The surgeon may think that he has succeeded in reaching the extreme depth of the wound with the nozzle of his irrigation apparatus, when it is really stopped some distance from that point by a layer of muscle or fascia which has become interposed, like a diaphragm, across the track by change in the position of the limb or by muscular contraction or relaxation in the wounded part. With careful attention to these points and the use of dry antiseptic dressings, such as iodoform gauze and alembroth wool, combined with rest and the application of a splint for this purpose, if possible, these wounds may be expected to follow a more satisfactory course than has been the case in the experience of military surgeons in former wars.

Lacerated Wounds.—Those, for instance, produced by fragments of shell, the bullets of case-shot, and such-like missiles, are peculiarly liable to the lodgment of foreign bodies; the projectile itself, shreds of clothing, or pieces of accoutrements frequently remain in them. In the treatment these should be looked for, and removed if found; the torn tissues should be replaced in their proper order as carefully as may be; hæmorrhage should be attended to, and tendons and large nerves sutured; the surfaces and the interstices of the wound should be well irrigated with a hot, weak antiseptic solution; iodoform should be lightly dusted on, and the wound covered with iodoform gauze wrung out of sublimate lotion, with an ample supply of alembroth or other aseptic wool over all. The difficulty of preventing suppuration is greater in the treatment of this class of wounds than in any other: hardly any amount of

care directed towards this desirable end will be completely successful, but the treatment above indicated will tend to reduce suppuration to a minimum.

Irrigation Solutions, and Dressings for Wounds.—Lord Lister has told us, in his post-graduate lecture on antiseptics, reported in the *British Medical Journal*, 1893, that he has returned to the use of carbolic acid, as, in his opinion, the best antiseptic for irrigation purposes. He tried, and at one time strongly recommended, perchloride of mercury in this connection; but further experience showed, that, while corrosive sublimate is a perfect inhibiter of bacterial growth, carbolic acid is a much more powerful germicide. The great drawback of the latter is that, even in weak solutions, it is irritating to living tissues, while sublimate solution is not so. On the other hand, corrosive sublimate, when applied to open wounds before they become shut off by granulation tissue, may be directly absorbed in such amount as to produce symptoms of irritant poisoning. Personally I have never seen this or any other evil effects follow irrigation with corrosive sublimate, but the records of such cases would appear to leave no room for doubt as to the fact.

Wounds which there is good reason to believe have not been contaminated, need no irrigation; but sword and bayonet wounds or lacerated injuries, all of which are so liable to have shreds of clothing, which are almost certain to contain micro-organisms, forced into them, and which can hardly escape the suppurative process unless so treated, should always be freely irrigated with one or other of the more commonly used solutions, 1–2000 or 1–4000 of corrosive sublimate, or 1–40 of carbolic acid, and hot (about 100.0° F.) in either case. The nozzle of the irrigating tube should be of glass, about nine inches long, and of the thickness of a cedar pencil, care being taken that its end has been smoothed by means of a spirit flame and a blow-pipe.

Antiseptic gauzes and wools for dressings to wounds are of great variety as to the particular chemical germicide with which they are impregnated. A considerable num-

ber of these are irritating to the sound skin around the wound, causing itching and eruptions on the surface and great discomfort to the patient. The double cyanide of mercury and zinc and the sublimate gauzes are of this nature; at the same time I may mention that the best surgeons use the double cyanide gauze with excellent results. Iodoform gauze is the least irritating of these preparations, if indeed it possesses any irritating qualities at all. In my own opinion a perfect dressing consists in pads of dry iodoform gauze in immediate contact with the wound, and thick layers of alembroth wool over it, extending for at least ten inches on all sides of the site of the wound, or incision, as the case may be. The bandages which fix the dressings should exert a firm and equable pressure on the sides and tracks of the wounds, so as to keep the cut or wounded surfaces closely approximated, and prevent the exudation or accumulation of serum or other fluid; special care should be taken that the bandages keep the *edges* of the dressings in contact with the skin, and for this purpose a few turns of elastic webbing outside of all are very useful.

The Use of Drains.—The tendency of the present day, amongst the best authorities, is towards limiting the use of drainage tubes. As greater care has been taken to avoid contamination of wounds, and in disinfecting those in which contamination has occurred, so the necessity for drainage has diminished. When all bleeding points have been ligatured, and when all ooze of blood has been stopped by lapse of time and the use of pressure, and the wound has been got into as dry a condition as possible, it may be closed without making provision for drainage. Drainage tubes are themselves a source of irritation and discharge, and provoke the necessity for their continued employment.

The irrigation of wounds with strong disinfecting solutions, which may sometimes be indicated, usually causes them at first to discharge freely, and drainage tubes should be inserted in such cases; indeed, in all cases where oozing of blood or discharge of serum may be expected, provision for the easy escape of fluids must be made. But the sooner drainage tubes are removed the better: when the

wound continues aseptic, twenty-four, or, at the most, forty-eight hours will be ample time to allow them to remain.

Incisions, and wounds which, by suturing, have been reduced to mere incisions, should be lightly dusted with iodoform and very freely covered with boracic acid powder. By the use of these powerful inhibiters of bacterial growth, "assurance is made doubly sure;" and if micro-organisms have managed to escape destruction and removal by the means employed for this purpose, they will fail to multiply and increase on such dry ground, and those fatal forms of surgical infective disease of which they are the cause will not arise.

Absolute rest to the wounded part is almost as important an item in the treatment of wounds as the dressing itself. For this reason splints of one kind or another should always be employed when the situation of the injury will permit, and this quite irrespective of any necessity of keeping broken bones in position. It is hardly putting the advantages of the use of splints in the treatment of extensive injury to the soft parts too strongly to say that its importance is only second to that of their application in fractures; in the latter case the treatment cannot, and in the former it should not, be carried out without them. Even when splints cannot be used, as in wounds of the chest and abdomen, firm bandaging with wide rollers tend to supply their want and promote the same indication, by lessening movement, and should be had recourse to when possible.

"First Field Dressings."—To obtain at the field hospitals and the dressing stations anything like the full advantages of antiseptic methods of treatment, wounds should not be interfered with at "the front" on the field of battle. The surgeons and stretcher-bearers who first attend to the wounded on the battle-field have no means available of rendering their hands and instruments aseptic, and infection is sure to occur if examination and exploration of wounds be allowed at the immediate front. Reyher, whose treatment, as already mentioned, was followed by unpre-

cedented results in the Russo-Turkish Campaign, gave instructions that wounds were never to be examined at the front, either with instruments or fingers; no operative procedures were to be undertaken except those absolutely necessary for the restraint of important hæmorrhage, or for the removal of a bullet lodged in the walls of one of the cavities of the body, whence it was liable to fall into a less accessible position. "For surgeons at the front," he says, "there is only one line of treatment—to occlude the wound, to lay the wounded part in a suitable position on the litter, and to render it provisionally immovable.[1] Nussbaum, of Munich, remarks that "the fate of a patient seriously wounded is almost entirely in the hands of the surgeon who applies the first dressing."[1]

An application for the purpose of aseptically occluding wounds on the battle-field has been adopted in the English army, as in all European armies. Each soldier on active service is provided with, and carries on his person, a dressing ready for immediate use. This is called the "first field dressing."

The first occasion on which a first field dressing was used by the English army was in the Crimea: it was merely a calico bandage and four pins, and was carried in the knapsack, a very unsuitable place, for it was seldom available when required. During the Ashanti War of 1873–74 a first field dressing was carried, which was composed of lint on which simple ointment had been spread, a triangular bandage, and some pins; it was folded into a small packet covered with wax-paper, and carried in the left breast pocket. In the Egyptian Campaign a similar dressing was carried by our troops.

In the Soudan Campaign of 1884 the dressing used was composed of two pads of carbolised tow, a gauze bandage, some pins, and a triangular bandage. It was wrapped in tin-foil, the outside cover being parchment paper secured by paste.

None of these dressings, except the last, had any pretensions to antiseptic properties, the only qualities which

[1] "Antiseptic Surgery," by W. Watson Cheyne.

tend to make a first field dressing of any surgical utility whatever.

Much ingenuity has been expended on dressings of this kind; all sorts of patterns have been suggested; whereas, in fact, the matter is perfectly simple. All that is required is a sufficiency of absorbent, and, above all things, sterile material to cover and protect the wound from dust and dirt, together with a bandage and one or two pins with which to fasten it to the injured part. A first field dressing packet must be of small dimensions; all the materials of which it is made up must be impregnated with some reliable chemical germicide, the less volatile the better; and it must be packed in such a way as to prevent its contamination from without. All these requirements are fulfilled by the dressing now in use in our army. It is an adaptation of the French field dressing, and is composed of a piece of gauze, a pad of flax charpie between layers of gauze, a gauze bandage 4½ yards long, a piece of mackintosh waterproof, and two safety pins; the antiseptic agent used is corrosive sublimate, 1–1000; it has an outer cover of cloth, sewn, and an inner cover of thin waterproof, cemented so as to make it air-tight. The directions for use are printed upon both the inside and outside covers.

The objects to be attained by the use of these dressings in the field are of great importance. In the present day, when so much attention is paid to the protection of a freshly made wound from outside dust and dirt, the advantages of the use of an antiseptic dressing on the field at the earliest moment cannot be exaggerated. It is hardly too much to say that it alone will render conservative surgery possible, but it certainly makes the difficulties of successfully employing this method in the field hospitals less than they otherwise must be. It meets the instinctive desire of most men to have their wounds covered from sight. And, again, after an important engagement, when the number of the wounded is sometimes very great, a large amount of unnecessary labour will be saved at the dressing stations when all the slighter wounds are found to be already dressed, and there is no absolute need for further inter-

ference with them until the patients shall have arrived at the field hospitals and the immediate pressure of work is less acute. They should be applied by the medical officers of corps or by their assistants, the trained regimental stretcher-bearers, or by the officers and men of the bearer companies.

CHAPTER V

GENERAL TREATMENT OF BULLET WOUNDS

THE division of bullet wounds into "simple" and "complicated" is a useful one; wounds being termed simple when the projectile has traversed unimportant soft parts only, and complicated when it has injured bones, large vessels, or nerves as well.

In the treatment of simple bullet wounds produced by small-bore projectiles, where the bullet has not lodged, nor other foreign body, such as pieces of clothing, or accoutrements, or fragments of stone[1] from ricochet shots, all that will be required is the thorough disinfection of the skin at and around the wounds of entrance and exit, with a trustworthy antiseptic solution, and the occlusion of the openings by means of dry, sterile, and absorbent dressings. The sides of the track should be held together by the firm and equable pressure of the bandages used in the application of the dressings, and complete rest should be ensured by the use of splints.

In these uncomplicated wounds there should be no interference with the bullet track. No object can be gained by such interference, and it only offers an increased risk of contamination. Esmarch gives similar advice regarding these simple injuries: he says, "Bullets nowadays do not often carry in foreign bodies with them, and wounds of this kind heal readily and without the discharge or slough which so frequently attended wounds caused by spherical bullets in former wars." In these cases of simple wounds by small-bore bullets, irrigation of the track is not required. On the other hand, simple wounds produced by

[1] Longmore, second edition of "Gunshot Wounds," p. 226, mentions some curious cases of teeth and pieces of bone from wounded comrades being made to act as secondary missiles and lodging in men's bodies.

spherical bullets demand greater care to render them aseptic, and irrigation should be practised. Missiles of this kind are much more likely to carry in shreds of clothing, and thus infect the wounds; and the bullets are themselves more open to infection with septic organisms than are modern rifle cartridges, which are carefully packed immediately after manufacture, and are only uncovered when required for use. La Garde, amongst other experimenters, found that the majority of bullets were sterile as they were taken from the original wrappers in which the cartridges were packed. On the other hand, he found that when bullets were purposely infected with pathogenic organisms before firing, the heat generated within the barrel or by the friction of the air had no effect in rendering them aseptic.

Examination of Gunshot Wounds.—The older works on military surgery declare, with all the argument and insistence possible, that there should be no examination or exploration of bullet wounds, if by any means it can be avoided. They say that even in those cases in which bones or joints have been injured, examination of the wound should only be made where it is necessary to discover the amount of bone damage in order to determine what operative interference shall be carried out; that where operation does not come to be considered, no exploration by probes or fingers should be made.

Surgeons of former times seemed to think that a routine exploration in every case of gunshot fracture was the outcome of an idle curiosity, the giving way to a desire for accurate diagnosis which was both harmful and useless. In this teaching they were perfectly logical, and only taught to others what a sad experience had taught themselves. They had observed that suppuration and septic surgical disease of all kinds occurred in wounds which had been examined and explored by means of instruments and fingers, and they observed this sequence of events so frequently that they considered that the relation of cause and effect was evident. Naturally, under these circumstances, they gave up the exploration of gunshot wounds as far as

possible, and laid it down as a law that these injuries should not be examined in this way for merely diagnostic purposes, but only when the surgeon had to determine how much of a limb he must amputate or what portions of a joint he must excise. But now, when surgeons have come to recognise that, with soap and water, a nail-brush, and an antiseptic solution at their disposal, they are provided with efficient means of rendering their instruments and their hands incapable of doing harm from infection when introduced into wounds, the teaching of the older military surgeons falls to the ground, and more modern methods of procedure are had recourse to.

In cases of simple perforation of the soft parts by small-bore bullets, where no foreign body has lodged (no fragment of the projectile and no pieces of the man's clothing or accoutrements), exploration of the wound is unnecessary, as these injuries usually heal almost by first intention. But even in these cases, if for any reason examination be deemed advisable, there is no reason whatever why it should not be made, with the proper precautions.

The case is, however, quite different when wounds complicated by bone injury, great or small, and more especially when those affecting joints, or so near joints that they may be suspected of affecting them, are under consideration. Gunshots of this nature demand a thorough examination and exploration for the purpose of ascertaining the amount of bone damage, as well as for determining what splinters require removal, and what operative measures, if any, should be undertaken. Nothing is more certain than that the outward appearances in cases of bone injury produced by small-bore projectiles convey no certain indications of the extent of the damage which may exist within; and nothing will supply information on this point except exploration with the finger. Exploration properly carried out can do no harm from its mechanical effect; and harm from contamination by micro-organisms should not occur, as it can be guarded against with practical certainty.

Exploration gives the surgeon most valuable information: it demonstrates to him the condition of the bone as

regards the degree of comminution; it shows him what splinters should be removed—and when bone is hit some splinters nearly always require removal; from it he ascertains the indications for and against operative interference, and the data on which to make up his mind as to what operation to undertake; or it may prove to him that conservative treatment is the proper line to adopt; and it renders it possible for him to make a prognosis. In fact, exploration places at the surgeon's disposal all the facts of the case, all the minutiæ of diagnosis so indispensable for treatment: without it all is guess-work.

Previous to the examination of a wound the surgeon's hands should be well washed with hot water and soap, using the nail-brush vigorously, especially to the finger-nails; they should then be rinsed in 1–20 carbolic lotion for a few seconds and washed in 1–40 lotion, again using the nail-brush. The instruments to be used should be sterilised by boiling; and the patient's skin around the wound should be washed with 1–40 carbolic lotion, having been previously shaved if necessary.

The necessity of exploration of small-bore bullet wounds was well exemplified in an experiment made at Netley. The case is reported in the *British Medical Journal* of June 2, 1894. I fired a Lee-Metford bullet, at fifty yards' range, with the service cordite cartridge, through a recently amputated leg. The bullet passed through the ankle-joint, entering the astragalus behind, above the articulating surface for the os calcis, and passing out in front through the neck of the bone. Both skin wounds were extremely small, less in diameter than the bullet. No deformity in the joint was apparent on external examination; there was no displacement of bone, and no crepitus was to be felt. It was, in fact, a case which, had it occurred in a living man, was, judging from external appearances only, eminently suitable for conservative treatment. But on dissection it was found that so much destruction had been produced within the joint that this mode of treatment must have ended in disappointment. Almost the whole astragalus was reduced to powder, and the bursting apart of this

bone had produced fissures in the tibia extending upwards for many inches, although the bullet itself had not touched the last-named bone. Only by thorough exploration with the finger, after enlargement of one of the apertures, could the true indications for sound treatment have been ascertained in this case, had it occurred on service. There was nothing in the appearance of the limb to lead one to suspect the extensive damage which had taken place within it.

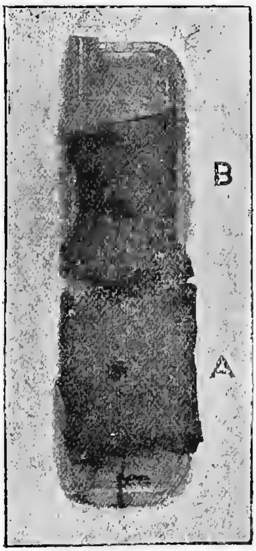


FIG. 26.

Bullet apertures in skin. A = entrance, B = exit. —*Netley Museum.*

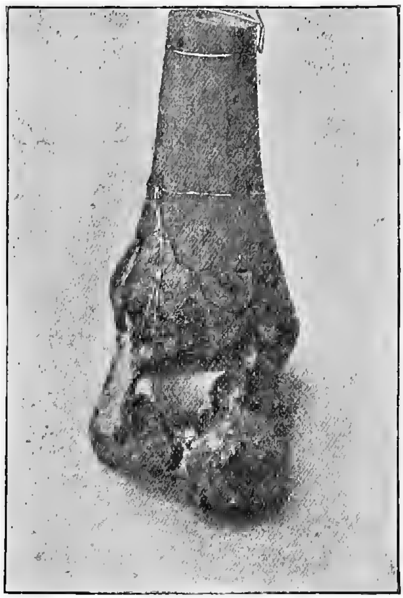


FIG. 27.

Effect of a Lee-Metford bullet on the ankle joint at fifty yards' range; the astragalus pulverised, and the tibia extensively fissured.—*Netley Museum.*

The drawing of this specimen is reproduced in the article on gunshot wounds by Surgeon-Major Andrew Duncan, I.M.S., in Mr. Treves' "System of Surgery," 1895, and the specimen itself is in the Museum at Netley. Fig. 26 shows the entrance (A) and exit (B) wounds in the skin in this case, and fig. 27 the condition of the bones.

Explorations, then, of all cases of bone injury by gunshot are correct and necessary procedures; but they must only be undertaken as the immediate preliminaries of the systematic treatment of the conditions discovered by their means, with the greatest possible precautions against infection of the wounds by micro-organisms, and with such care and gentleness as will ensure that no further injury be caused to the torn tissues. Under no circumstances are they to be made at the immediate front on the battle-field itself, if good results are to be obtained and modern surgery practised at the field hospitals. The duty of the surgeons working close in rear of the fighting line, as regards the treatment of wounds, is to cover them as quickly as may be with a first field dressing; to avoid contamination of wounds by dirty hands; and to prevent contamination during the time which must elapse before treatment can be commenced, by covering them with aseptic occlusion dressings. There are no means, and there is no time, for surgeons and dressers at the front to asepticise their in struments and hands with the necessary care before examining a wound, and the first places where these will be available will be at the bearer company's dressing stations and at the field hospitals.

The Method of Exploration.—The clothing over the wound should be examined, in order to ascertain whether or not it shows loss of substance, so that an opinion can be formed as to the probabilities of shreds of cloth having been carried in. If this has occurred, it may be well to irrigate the track, and this should certainly be done if efforts to remove the foreign matter have been made with instruments.

Pfuhl's[1] experiments go to show that the degree of virulence of the micro-organisms usually contained in the clothing even of men employed in dissecting-rooms is so low that they are unlikely to produce suppuration when present in wounds, and, in fact, in his experience they never did so; while Coler draws attention to the fact that pieces of clothing so seldom cause infection that the prob-

[1] *Zeitschrift für Hygiene*, vol. xiii., 1893, p. 487.

ability of their presence in wounds may be disregarded. Nevertheless, irrigation under the circumstances referred to will be the safer plan. Projectiles of small diameter do not carry in shreds of the clothing so frequently as the large round bullet did, and in the German report this is stated to have occurred only in about 12 per cent. of the hits.

In making an exploration of a gunshot wound for the purpose of discovering the situation of a bullet which has lodged, or to ascertain the condition of a fractured bone, the introduction of the finger gives the best information. By it the bullet may be reached; but if not the surgeon will certainly be made aware of the degree of comminution which has been produced in the broken bone, the amount of displacement which the fragments have undergone, what adherence to the periosteum they still maintain, and which splinters require removal. If the entrance side be selected for the examination, the skin wound made by a small-bore bullet will probably have to be enlarged, and in any case the limb or part should, if possible, be placed in the position in which it was when hit. Should the finger not reach the bullet, and evidently not pass to the bottom of the track, recourse must be had to other means.

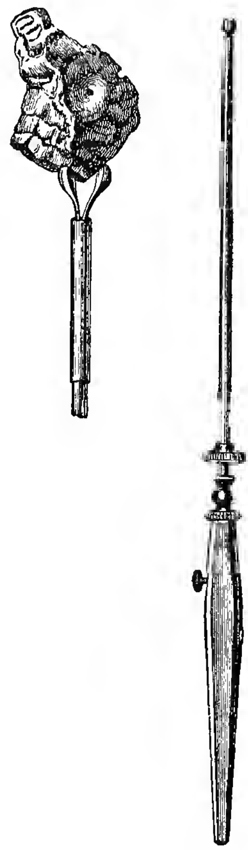


FIG. 28.
Lecomte's Stylet-Pince.

Bullet Detectors.—The instruments which have been devised for the detection of bullets lodged within the body are constructed on two principles: those which bring away on their points portions of the metal composing the bullets, and those which indicate the presence of the projectiles by

the agency of electricity. The two of the former kind, which have hitherto been of great service in this connection, are Lecomte's *stylet-pince* and Nélaton's probe. The probe-nippers invented by M. Lecomte, a French army surgeon, is so constructed as to be capable of biting off a small piece of any soft metal and bringing it away grasped within its jaws. Its mode of action will be best understood from a glance at the accompanying figure. The canula glides backwards and forwards, opening and closing the steel jaws of the instrument.

FIG. 29. Nélaton's Probe.

Nélaton's probe is a long probe having a round white knob of unglazed china at one end, which, when rubbed against lead, takes a mark similar to that made on paper with a lead pencil, and thus indicates the presence of a leaden bullet if it be lodged in a situation out of sight. The principle of this bullet detector was suggested to Dr. Nélaton by M. Rousseau, a French chemist, and it was first used in Garibaldi's case of bullet wound of the ankle-joint, where the lodgment of the bullet was proved by it.

Both of these instruments have done excellent service, and will continue to give good results in the detection of leaden bullets; but they are quite useless for employment with modern bullets having hard mantles. The steel or cupro-nickel envelopes of small-bore projectiles are not affected by either: Lecomte's nippers fail to bite into them, and the china of Nélaton's probe takes no stain. They may therefore be set aside as useless for the purpose of exploring for these missiles.

Electric Bullet Detectors.—A large number and various patterns of bullet detectors, the action of which depends on electricity, have been invented. With one exception, they are all made on the principle of a probe composed of some insulating material containing two conducting wires, the points of which can be made to protrude at the end of the probe, but are separated from each other by a short interval, about one-sixteenth of an inch;

the conducting wires are connected with a small battery and with a bell or a galvanometer. The circuit is, of course, interrupted at the point of the probe by the separation of the two wires; but contact of both wires against metal, as a bullet in a limb, completes the circuit, and this is indicated by the ringing of the bell or the movement of the galvanometer needle.

Instruments made on this plan are thoroughly efficient, if only all the conditions necessary for their proper working be fulfilled. But in practice certain difficulties are experienced: the batteries are very liable to get out of order, and they often required to be sent away to an electrician to be repaired; in consequence of the sharp curve of the sides of a bullet it is very easy to fail to make *both* points touch at the same time, in which case the circuit will not be made; and, again, even a thin layer of tissue over the bullet will prevent the contact of the wires and act as a non-conductor, preventing the completion of the circuit and the effective working of the instrument.

Pratt's electro-probe is an instrument which is not subject to the great objection that pertains to all other bullet detectors depending on electricity—the liability of the batteries to getting out of order and failing to work at the moment they are most required. Surgeon Lieutenant-Colonel Pratt, A.M.S., has designed an electro-probe, the battery of which, although a weak generator of electricity, is quite powerful enough for its purpose when combined with a microphone for multiplying the sound produced on making and breaking circuit. The use of the microphone for this purpose is not new. A "microphonic bullet probe" has already been made and patented by Albert Klein, of Ghent; but the special excellency of Surgeon-Colonel Pratt's instrument rests in the battery which he has had made for it, as it is practically indestructible, and can hardly get out of order. The battery consists of a cylinder of ebonite, on which small plates of copper and zinc are fastened alternately, the connecting wires coming off at either end of the cylinder. A weak current is generated in the apparatus by wrapping two pieces of lint

wet with salt solution around the metal plates. The bullet forceps forms one electrode, while the other may be any piece of metal which can be held in the patient's hand or put into his mouth. The microphone is in the circuit, and is suspended over the operator's ear, but the circuit is not complete until the forceps touches any metallic substance which may be lodged in the patient's body. On making and breaking the circuit a slight crackling noise is produced in the microphone and heard by the surgeon. The sound is not loud, but it never fails to be audible, and it is ample to answer the purpose it is required for. Touching any other substance than metal with the forceps gives no sound in the microphone; the instrument cannot, therefore, mislead the surgeon when searching for a lodged missile. The Pratt electro-probe is probably the most trustworthy electric bullet detector yet invented.

Bullet Extractors.—The lodgment of a bullet in the wound having been ascertained by means of one or other of the appliances just referred to, its removal will have to be undertaken either immediately or later on in the course of the case. An almost infinite variety of instruments have been invented for the extraction of bullets. They are mostly of two kinds—those which act as forceps and those which act as screws. Forceps of almost every possible shape and design have been made according to the taste and originality of the surgeon. In a certain number of cases the dressing forceps of the pocket-case will suffice, but only when the bullet happens to be lodged near the surface. Under other circumstances the difficulties must be met by means of more suitable instruments.

Bullet extractors on the screw principle have never been much in favour with English surgeons, but on the Continent they have been more used, a type of the class being the *Tirefond* extractor of the French army, or Bauden's extractor. The point of this instrument is sharp, and furnished with a double screw-thread which is covered with a canula during introduction into the wound. This screw extractor readily fixes itself in a soft leaden bullet and removes it with comparative ease, but it is

quite useless for the extraction of bullets with hard envelopes.

A large number of extractors, some of them on the principle of forceps and with every variety of blade, and others with different mechanical arrangements for seizing the bullet, have been invented; but it is unnecessary to describe them in detail, as they are now practically out of date, and only to be seen in museums. The most efficient bullet extractors are now admitted to be forceps of one kind or another.

The qualities to be desired in a bullet forceps are that it should be of such a size and shape as to be easy of introduction into the bullet track without causing injury to the tissues through which it passes; the hinge should be placed so far back that a very slight separation of the handles opens the blades sufficiently to admit the bullet between them, thus avoiding over-distension and tearing of the skin wound; the grip of the blades on the bullet should be strong; and it should have a spring-catch mechanism at the handles similar to that on the Spencer Wells artery forceps.

A considerable number of bullet forceps have been made on the principle of the vulsellum, having two, or four, or even six mouse-toothed claws in the blades for the purpose of securely holding the bullet. These instruments certainly do grip the bullet with great power; but they are most objectionable and dangerous bullet extractors, all the same. When searching for a bullet at the end of a long track, and when the blades are brought together in the attempt to seize it, if the foreign body is not gripped, the soft parts must be entangled in the sharp teeth of such an instrument, and most serious damage may be done if important structures, such as large vessels and nerves, are torn. Longmore remarks, in this connection, that "penetration of the tissues is only made known (to the operator) when traction is made upon them in the process of withdrawing the instrument from the wound or by subsequent inspection." "The penetrating power and firm tenacity of grasp of such pointed instruments when

they are applied to substances capable of being penetrated by them, is undoubtedly very great. No forceps depending on sharp points for its grasp can be employed without causing unnecessary hazard to a wounded man whenever the foreign body to be removed is not in view, for injury can be so much more readily inflicted by a pointed instrument, and so much more unconsciously to the operator,

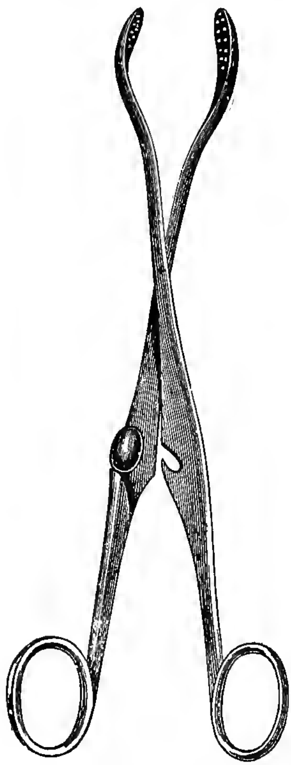


FIG. 30.
Midwifery-Hinge Forceps.

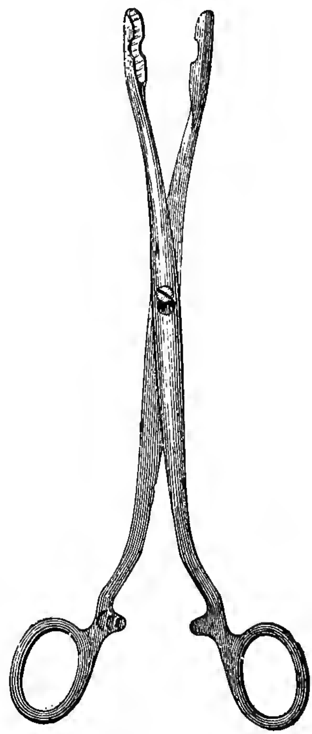


FIG. 31.
French Forceps.

than can happen with extracting instruments which terminate in blunt, smoothly rounded blades, when they are properly used." [1]

Forceps are now used by all military surgeons, English and foreign, for the extraction of lodged projectiles and

[1] Longmore, second edition, page 474.

foreign bodies of all kinds. The old midwifery-hinge bullet forceps (fig. 30) was a very useful instrument for the removal of fragments of shell, stone, or other foreign bodies, but unfortunately it is not now included in the English army field case. The French army bullet forceps (fig. 31) is a well-made instrument, and suitable for its purpose, its fault being in the position of the hinge, which is placed

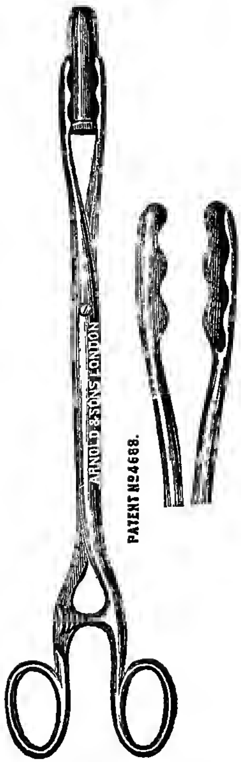


FIG. 32.
Author's Forceps.

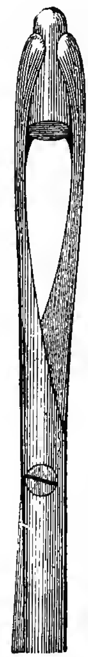


FIG. 33.
German Forceps.

nearer to the points than it is to the handles, necessitating too wide a separation of the latter in order to grasp the bullet.

Messrs. Arnold & Sons, London, have made, at my suggestion, the bullet forceps figured above (fig. 32). When closed, this instrument passes readily into a bullet

track; its blades fit over, and take a firm hold of bullets of the modern small-bore patterns, and on failure to grasp the missile, they cannot injure any soft parts which may fall between them. Sir Thomas Longmore considered that it answers all the requirements of a forceps for the extraction of modern small-arm projectiles. In the plate the hinge is shown too far forward. Fig. 33 represents the German bullet forceps.

The entrance wounds made by small-bore bullets through the skin and fascia will nearly always require to be enlarged for the removal of lodged bullets; these apertures are so small that the introduction of the finger, or even of the forceps, will usually be impossible without this. The tracks through the muscles will not need enlargement; they are of considerably larger dimensions than the skin wounds, and they are punched-out channels, showing distinct loss of substance, of much greater diameter than the projectiles which produce them. A bullet track in muscular tissue is quite different from the track made by a bayonet: in the latter the tissues are merely torn apart by the passage of the weapon, no open tunnel being left on its removal; while in the former a channel remains, through which a slender instrument can be passed without difficulty if the muscles be placed as nearly as possible in the same position which they held when traversed by the projectile.

The Extraction of a bullet, or other foreign body, from a wound, should be done with great gentleness and deliberation. If not placed too deeply, the finger should be inserted into the track until the bullet is felt, and then a director, or a scoop, or a narrow-bladed forceps passed along it. If the bullet will not move on the application of gentle force, it may be that the forceps or other instrument is separated from it by a layer of fibrous or muscular tissue which is keeping it fixed, and this will be capable of detection by the tip of the finger. This should be cleared away or torn through by means of the finger-nail, and the bullet seized again. If the bullet is at too great a distance from the surface to be reached by the finger, the bullet

forceps must be used. The forceps should be completely closed during introduction and until the bullet is felt against its point, as in this way the soft parts in the vicinity are avoided, and prevented entering the triangular space formed between the points of the open blades and the hinge. No traction should be made until a firm and certain grasp of the bullet has been obtained. If the bullet moves a little and is then held, the forceps should be released, and reapplied at another situation for another attempt at removal. Bullets are very liable to slip away from the closing blades of a forceps, and this difficulty may be met if the parts on the far side can be grasped with the surgeon's left hand and pushed towards them. In this way the bullet is steadied and the track shortened.

In exploring for bullets, either for the purpose of diagnosing their situations or with a view to their extraction, efforts should not be persevered in for too long a time, and care must be exercised not to use undue force in extracting them, either when impacted in bone, or when, having become altered in shape, they are evidently entangled in the softer structures. After a time, either the situation will become capable of diagnosis, or, if this was not doubtful, the bullet will become loosened, and can be removed without difficulty.

But it is desirable to remove bullets immediately if possible. Macleod, in his "Notes of Surgery in the Crimea," says: "Those who have studied gunshot wounds in the field know full well how great is the irritability caused by the presence in a wound of a bullet or other foreign body; how restless a patient is until it is removed, and how prolonged is the period of treatment in cases in which it is left: hence the desirability of removing it." When the bullet has been removed, or if we have been compelled to desist from further attempts to remove it, the track should be thoroughly washed out with an antiseptic solution, and care should be taken to provide drainage by the usual means. The skin wound should be covered with a dry absorbent dressing of gauze and wool, and the sides of the

track should be approximated and gently compressed by a well-adjusted bandage.

When a bullet is impacted in bone, it may sometimes be released, if the bone in which it is fixed is sufficiently close to the surface for such manipulation, by chipping away some small pieces at the edges of the cavity containing it, by means of a small gouge, and then using the instrument as a lever for the loosening of the projectile.

In cases where bullets cannot be reached through the wound of entrance, or where, on account of change of shape and entanglement in the tissues, they cannot be extracted through the original track, they may often be removed without difficulty through a new incision at the opposite side of the limb or body. In performing this operation the bullet should be steadied with the left hand, and care is required to make certain that the point being cut down upon is the bullet, and not a natural bony prominence. Longmore and other writers detail many instances in which this mistake has been made in the hurry of field surgery, though at first sight it does not seem a probable one to make.

In dressing wounds which have been irrigated and thus subjected to the influence of germicide solutions, and which are on that account likely to discharge somewhat freely at first, dry absorbent dressings, no doubt, act as drains by their hygroscopic qualities; but in addition to this it is advisable to provide in these cases for drainage by means of tubes.

The Administration of Food and Stimulants.—The treatment of wounded men, on the field and at the dressing stations, by the administration of stimulants and nourishment, is of the very greatest importance, and cannot be overlooked if our treatment of their injuries is to produce good results. Soldiers on active service are often likely to be in low condition, more or less worn out by fatigue and exposure, and by the want of rest and good food. Amongst the wounded, and especially amongst those who have suffered from severe hæmorrhage, the great exhaustion which rapidly supervenes is almost a greater danger to life, for

the first few days, than is the wound itself. It will be necessary to meet it at the earliest moment with such kinds of food as are nourishing, stimulating, and restorative. These, to be always ready and available, must be capable of being kept fresh and in good order for some time, and they must be in concentrated forms to be easy of transport. Amongst such are the tinned and sealed preparations; extracts of meat, peptonised and otherwise; meat biscuits; soups; extracts of tea, coffee, and malt; condensed milk; chocolate, cocoa, &c., &c. Little can be done in this matter while the men are lying on the field; but even there a small quantity of alcohol and water may be given when necessary to stimulate the flagging circulation and enable men to bear the movement to the dressing station.

At the dressing stations liquid nourishment of the kinds above indicated should be in readiness on the arrival of the patients, and its administration should be attended to even before the injuries themselves are examined or treated. It is not, of course, at this time a case of giving substantial food, but merely of supplying wounded men with food materials sufficiently restorative to preserve their vital forces and arrest exhaustion, and so fit them to bear operations which may be necessary, and possibly enable them to commence a journey towards the base. At such a time, and for these purposes, we may confidently expect the best results from the use of alcohol, meat extracts, eggs, milk, chocolate, &c., &c.; and the more we recognise and administer to the necessities of wounded men in these respects, the better will be the results of our treatment of their injuries.

As I mentioned just now, we must remember that the chances are that at the time men receive wounds they will be in a low state of nutrition and vital power, aggravated probably by a fatiguing forced march which so frequently precedes a battle; their wounds further lower and depress men already depressed by other causes, and thus their necessities in the matter of stimulating and restorative food require the first attention of the surgeon in the field.

The Germans found that, through inattention to these details of early feeding, a considerable number of wounded men succumb during the first few days after an engagement, not as an immediate consequence of their injuries, but from a complete exhaustion of their general vitality.

In addition to the ordinary risks which all wounded men must run from their injuries, the wounded soldier is subjected to many special ones dependent on the peculiarities of the circumstances of the case. He may, from the unavoidable conditions of warfare, be left lying on the field for an unusually long time, or a long interval may elapse before he arrives at a field hospital, his wound becoming septic and inflamed before he reaches it: he is subjected to frequent moves from one hospital to another, thus coming under the treatment of many surgeons, who may not always be agreed upon the necessary line of treatment; hence men with aseptic wounds may pass into the hands of surgeons who are not followers of Lister and believers in the germ causes of surgical disease, the result being that clean wounds become septic. When, from these or other unavoidable circumstances, wounds take on a septic action and the patients come again under the care of men who have clearer views of modern surgery and its capabilities, it will become the duty of the latter to make every effort to recover the lost ground and render the septic aseptic, and we have good evidence to prove that we may to a great extent be successful in doing so.

Dr. Cammerer, surgeon-general of the German army, has published his experiences in this respect in the last Russo-Turkish War. He writes:[1] "The cases came from Plevna, and had been subjected, to three, four, and five days' previous transport, and arrived with wounds already swollen and inflamed. Yet, although an interval of seven days had occurred in some of the cases since the receipt of the injury, these septic wounds were converted into aseptic ones by repeated washings with 5 per cent. carbolic lotion and the application of moist carbolic and jute dressings. The surface of the part injured was first washed with soap

[1] "Antiseptic Surgery," by Wm. MacCormac.

and carbolic lotion, shaved and washed again; all foreign bodies were removed, ill-conditioned granulation tissue scraped away, 8 per cent. solution of chloride of zinc applied, careful drainage arranged for, and jute dressings externally, which were changed every twenty-four hours." "All the surgeons unite in stating that after an interval of even so long as fourteen days gunshot wounds may be made aseptic."

Referring to the good results obtained by the German surgeons in the Russo-Turkish War in the treatment by antiseptics of wounds which had become septic, and when long intervals had elapsed since their receipt, MacCormac remarks: "It shows that, however valuable the primary antiseptic treatment of such wounds may be, a secondary antiseptic treatment may also produce excellent results."

The late Surgeon-Colonel Godwin[1] reported his experience in this connection at Suez in 1884. The patients arrived by ship from the Soudan after nine days' journey, with septic wounds in every instance; but by the diligent use of antiseptics most of the wounds improved, suppurated less, and became fairly healthy.

It is, probably, impossible to treat a suppurating and septic wound with antiseptics so that it will be brought to the condition it would have been in had it been so treated from the first; we may not, perhaps, achieve in it that wholesome and absolutely dry condition of a "primary aseptic" wound. But by the persistent use of antiseptics a changed condition will occur in it which is of incalculable value to the patient himself towards recovery, as well as to his wounded comrades occupying the same hospital, as a protection against the spread of infective disease. As the number of septic cases increases in a surgical hospital, so their severity increases; as micrococci pass through one organism after another, so their virulence becomes accentuated and the percentage of deaths to cases augments. Not only do surgical septic diseases increase in numbers during the later stages of a campaign as compared with the earlier ones, but the gravity of the individual cases

[1] "Reports, Army Medical Department," vol. xxv., 1883.

and the mortality resulting from them increase also. In former times "a want of good sanitary surroundings" was held to be responsible for this state of things; it is now recognised that the real insanitary fact to which it is due is the gradual accumulation in hospitals of large numbers of surgical cases. Suppuration reproduces itself in an ever-increasing ratio once it begins amongst wounded men; one case may produce a dozen others, these a hundred others, and so on. Hence the importance of treating the wounded in war hospitals aseptically from the first as far as may be, and of taking immediate action to suppress suppuration when it occurs.

In the treatment of suppurating wounds, irrigation, drainage, and dry absorbent dressings frequently renewed are the means to be relied on. The best procedure is to wash the wound to its deepest recesses with an 8 per cent. solution of chloride of zinc, having previously scraped away the granulations with a Volkmann's spoon, and then thoroughly irrigate it with a 1–20 carbolic solution, these irritating germicide solutions being subsequently removed by irrigating with boiled water; provision for complete drainage should then be made, and the dressings applied.

During the first few days these wounds should be dressed twice a day after the same plan, only omitting the zinc solution. By these means they will be brought into a healthy condition, and the suppuration will gradually decrease. MacCormac points out that the difficulty in this treatment consists in the complete disinfection of the wound in its more inaccessible parts and in its efficient drainage. "When this could be done, the wounds, without exception, became aseptic after four or five dressings." Mr. Watson Cheyne has recommended that the surfaces of septic wounds should be lightly painted with pure carbolic acid, and I have latterly had good results from this method.

Secondary Hæmorrhage.—A complication attending septic wounds, which has hitherto given rise to great anxiety and difficulty, is secondary hæmorrhage. In former campaigns it has always been a common complication and a cause of great mortality in war hospitals. It is now known

to be one of the direct outcomes of septicity in wounds in a large proportion of cases. MacCormac, in his "Notes and Recollections of an Ambulance Surgeon," refers to the causes of secondary hæmorrhage. The occurrence of this complication "indicates," he writes, "that the fluids of the organism are vitiated by some poison, pyæmic or otherwise." "The great frequency of secondary hæmorrhage has for its chief cause the absence or faultiness of sanitary conditions," meaning that suppuration in wounds is likely to occur under these circumstances, and give rise to the complication under consideration.

Sir Thomas Longmore writes: "Secondary hæmorrhage is by no means an infrequent complication of gunshot wounds. It is particularly liable to occur in wounds which are attended with a sloughing action, and especially when the sanitary condition of the hospitals in which the wounded men are treated is bad, or the wards are overcrowded." And again: "No wounded patient can be considered to be safe from seoondary hæmorrhage so long as his wound remains open and suppurating."

Mr. A. Pearce Gould[1] says: "Idiopathic secondary hæmorrhage occurs in all cases from disintegration of the arterial wall by septic arteritis. It is met with in abscesses, ulcers, and infected wounds opening into a neighbouring artery." The coats of vessels which are bathed in pus for any time, and are thus subjected to the influences of the chemical products of the fermentative changes which occur in animal fluids owing to the presence of pyogenic cocci, undergo a process of softening, and are ready to give way on the occurrence of some slight movement of the part or other accidental cause, and secondary hæmorrhage is the result.

Erichsen[2] puts this matter of the causation of secondary hæmorrhage from suppurating wounds forcibly in a few words: "Of all means of avoiding this accident, however, the prevention of septic processes in the wound is by far the most important. Secondary hæmorrhage may be said

[1] "A System of Surgery," by F. Treves, 1895.
[2] "Science and Art of Surgery," tenth edition.

never to occur in a wound healing healthily without suppuration."

But, in the case of gunshot wounds, other causes play an active part in the production of secondary hæmorrhage. In the first place, a vessel may be so slightly grazed by a bullet in its passage through the tissues that, although no aperture may be made in it at the moment, its coats are so severely contused that sloughing of its walls takes place many days later, giving rise to severe bleeding; and, in the second, a splinter of bone may be displaced, and its sharp and jagged edge may come to rest and press against the side of an artery, causing ulceration at the point of contact. And, again, in the same degree as absolute rest to the patient and immobility of the part are essentials in the satisfactory treatment of all injuries from which secondary hæmorrhage is probable, so, in the same degree, is the enforced transport, to which wounded soldiers are so frequently exposed, a special factor in the production of this accident in them, and one requiring consideration in determining the primary treatment of the case as well as that of the complication itself when it supervenes.

The Treatment of Secondary Hæmorrhage.—In the treatment of *primary* hæmorrhage, methods which might be termed palliative or temporising, such as the use of the actual cautery, pressure, flexion, &c., &c., may with safety be had recourse to, and they may be varied and repeated again and again if the bleeding recurs; failure of an attempt to stanch primary hæmorrhage by one or other of these means does not indicate immediate ligature of the main vessel or amputation of the limb. But it is quite otherwise in the case of secondary hæmorrhage. Here, if the first efforts at this class of treatment are not successful and the bleeding returns, more effectual and certain means for its arrest must be immediately adopted; no delay is permissible if the patient's life is to be preserved. Mere cessation of the blood-flow must not be trusted to. When secondary hæmorrhage once occurs, it may cease spontaneously from temporary clotting at the aperture in the vessel, but it will surely recur again and again until effective

means have been had recourse to for its permanent prevention. The available methods of treatment for this complication of gunshot wounds are—(1) plugging and pressure at the site of the bleeding; (2) ligature of the vessel in the wound; (3) ligature of the main artery of the limb; and (4) amputation.

On the first appearance of secondary hæmorrhage from a suppurating gunshot wound, if in one of the limbs, the blood pressure in the vessel should be lessened by the application of a tourniquet higher up; the wound should be plugged with gauze, and a compress put on under firm pressure. If, as is probable, this prove insufficient and the bleeding is repeated, the circulation should be fully controlled by an elastic tube, while the wound is being opened up, the clots turned out, and efforts made to tie the vessel in the wound.

This is a most difficult operation to carry out under the circumstances, for all the tissues are softened and broken down, and the vessel itself, when found, is friable and almost incapable of holding a ligature; but it is the ideal treatment, and every effort should be made to carry it out. The wound must be thoroughly disinfected, as a preliminary to securing the artery, for, unless this be satisfactorily done, the original cause of all the mischief will remain and continue to act, tending towards a repetition of the complication. The wound must be well dried out with antiseptic cotton-wool swabs, and the vessel sought for, the tourniquet being slightly relaxed to indicate the situation of the bleeding point. If the hæmorrhage be found to be coming from an aperture in the continuity of an artery, ligatures must be applied above and below the opening, and as far apart as possible, the vessel being severed between them; if from either the proximal or distal end, this should be cleared from the surrounding tissues until a sound portion of the vessel is reached, where it may be tied, or acupressure may be used instead.

Mr. Pearce Gould recommends the application of the actual cautery at a dull red heat, and for a long time, so as to completely char the end of the vessel and the surround-

ing tissues, in cases where ligature of the vessel in the wound is found to be impracticable from softening of its coats, and also in cases where the bleeding does not proceed from one artery, but is rather a "parenchymatous oozing." Here there are no vessels to tie, and "the whole surface may be seared with the hot iron," or powdered sulphate of iron may be dusted in.

When secondary hæmorrhage proceeds from the deep arteries of the neck, abdomen, and groin, no treatment but disinfection of the wound, plugging it with gauze, and pressure, is attainable; but the majority of these cases die.

When these methods of treatment at the site of the hæmorrhage have failed, if the wound be in a limb, we have still the operations of ligature of the main artery at a distance, and amputation, to fall back upon; but it must be clearly understood that even the former of these procedures should only be undertaken as a last resource, after failure to tie the vessel in the wound, or on recurrence of the hæmorrhage following the successful performance of this operation. The rules which govern the surgeon in tying the main artery of a limb for secondary hæmorrhage occurring after ligature in the continuity of the vessel lower down, are applicable in cases of gunshot wounds in which this complication presents itself. The conditions of both cases are quite comparable, and in neither are the results very satisfactory. In both cases there is an interruption to the main circulation of the limb, and in both a second block is applied by operation higher up; gangrene, therefore, very commonly results, especially in the lower limb, where, indeed, it is almost certain to occur. When gangrene does not take place, it is because the collateral circulation becomes well established, and this very condition renders a recurrence of the hæmorrhage at the wound from the distal end of the vessel almost inevitable.

Speaking in general terms, all surgeons agree that, even in civil practice, the Hunterian operation for secondary hæmorrhage in the lower limb should not be performed. In the case of the upper limb it is a less unfavorable procedure, because gangrene is less likely to occur from the

second interference with the blood supply. When it fails, and the hæmorrhage recurs, or when the situation of the bleeding, as in the leg, contra-indicates it, amputation is the only treatment left.

In civil practice, therefore, secondary hæmorrhage in the lower limb, when it persists after ligature in the wound or where this cannot be done, is almost always treated by amputation at or a little above the original site. Erichsen has seen "a few rare cases in which ligature of the popliteal has succeeded" for secondary hæmorrhage from the tibials, but is strongly of opinion that amputation even here is the proper treatment to adopt. In the upper extremity the proximal ligature may be used with a fair expectation of success, but amputation should be immediately performed if the hæmorrhage recurs. I have notes and a very vivid recollection of a case I saw treated many years ago: a wound of the deep palmar arch had been treated by pressure, after failure to tie the vessel in the wound; secondary hæmorrhage occurred on the fourth day; pressure in the palm was again tried, and failed; the radial and ulnar were tied close above the wrist, but the hæmorrhage recurred, and the brachial was ligatured; then gangrene set in, and the man died.

Owing to the exigencies of military service it will frequently be found necessary to perform amputations in cases which, if they were being treated in the quiet of a civil hospital, would probably be subjected to less radical methods. This usually results from the imperative necessity of transporting wounded men from the front towards the base of operations. The hospitals in which the wounded are treated at the front are movable field hospitals, and must be evacuated as soon as possible, so that they may be ready to move forward with the army. Men on whom conservative treatment is being carried out, or who have had joints excised, are not suitable for transport. When, therefore, wounded men have to be moved, in order to permit of the further advance of the field hospitals, and of the transfer of the wounded themselves towards the base, amputations will often have to be performed in cases

which, under other circumstances, would have been differently treated. But this unavoidable transport of the wounded towards the rear does not play any part in rendering amputations more frequently necessary in cases of secondary hæmorrhage. By the time this complication can supervene, the patients will, most probably, have arrived at the base of operations, or, at all events, they will be under treatment in the stationary hospitals on the lines of communication, places suitable for serious cases, and from which even the circumstances of warfare can only exceptionally necessitate the removal of such patients.

Nevertheless the military surgeon will, for other reasons, often be compelled to perform amputations, even in the upper extremity, for secondary hæmorrhage under conditions where his civil colleague would still deem ligature of the main artery of the limb the proper method. When a first outburst of secondary hæmorrhage has been treated by pressure, or by ligature of the vessel in the wound, the patient requires careful and skilled watching by a person competent to take immediate steps for the temporary stanching of the bleeding, should it recur, and surgical assistance must be available at a moment's notice to carry out the necessary operative procedures. These requirements it will frequently be difficult or impossible to supply in a military hospital in the field, crowded as it may be with wounded men, the attendance on whom and the dressing of whose injuries might well fully occupy the time of twice the available personnel. The personnel of hospitals in the field is fixed at the number which will be required to work them in times of average requirements rather than at that which might be advisable on exceptional occasions. Dependence, therefore, cannot always be placed on having an ample supply of surgeons and skilled attendants, and the energies of both these classes of persons will be required in the active work of the hospital, not in merely watching critical cases. For these reasons I think it will be apparent that amputation is the correct treatment for secondary hæmorrhage in a larger proportion of cases in military than in civil practice; and

if asked to formulate, in the fewest words, the treatment of this complication of gunshot wounds, I would say—(1) disinfection of the wound and ligature of the bleeding vessels in it; and, on a recurrence, (2) amputation at, or a little above, the site of injury, and this whether the upper or lower limb be implicated.

Treatment on these lines will tend to lessen the mortality rate of a most serious and fatal class of cases; although, of course, it may sometimes happen that the Hunterian operation may be had recourse to in the upper extremity when the circumstances of the hospital, as regards the number of patients to be attended to, and the work to be done, will permit of it. The following table from the "Surgical History of the War of the Rebellion, U. S. A.," gives valuable information in this connection:—

Summary of 2235 Cases of Secondary Hæmorrhage Showing Treatment and Results.

Treatment.	Cases.	Recovered.	Died.	Percentage of Deaths.
Hæmorrhage followed by amputation	294	122	172	58.5
" " " compression	786	262	524	66.6
" " " ligature	720	328	392	54.4
" " " ligature and subsequent amputation	87	34	53	60.9
" from stumps after amputation	348	109	239	68.6
Totals	2235	855	1380	61.7

The mortality in the same war following ligature in the wound was lower than any of the above, viz., 43.6 per cent.

The General and Constitutional Treatment of Hæmorrhage.—When a patient has suffered a considerable loss of blood, whether it be as a primary or as a secondary complication of injury or operation, his general treatment, to enable him to tide over the consequent weakness and anæmia, becomes of great importance. The indications are to keep him in a state of absolute rest and quiet, to get his temperature again up to the normal and to maintain it, and to supply him with food material of the most nourishing and most easily digestible kinds, while at the same

time it is unstimulating. The horizontal position in bed, if it be possible, with the head low, is the best. The danger to be apprehended from movement of the injured part should be explained to the patient; the limb should be fixed by means of a suitable splint, and slung, as by the latter means the unrest so frequently seen in men suffering from the effects of great loss of blood will have less disturbing consequences on the injured part itself. Hot bottles should be placed around him in bed, and he should be covered with well-warmed blankets, care being taken to leave the respiratory movements quite uninterfered with, and hot drinks should be given to him. The food should be composed principally of milk, eggs, beef-tea, and such-like nourishing liquid foods, and, until the temperature has recovered itself, food should be given hot. If the patient be in a very low and collapsed condition, stimulation with hot spirits and water, or by the subcutaneous injection of 30 minims of ether, must be risked; and under these conditions firm bandaging from elbow upwards of the uninjured limbs may have good results, by tending to ensure a fuller blood supply to the brain and other vital organs.

Transfusion.—Since it was discovered that as good effects are produce by the intravenous injection of saline fluid as of blood, the operation of transfusion, in cases where death is threatening from loss of blood, has been practically abandoned. The former plan is much the simpler of the two, and it is not open to the objections of the latter. The original theory of the good effects of transfusion was that they depended on the replenishing of the blood lost by the patient by the blood of the donor; but Dr. William Hunter showed, in 1889, that this is not the true explanation of the results to be obtained from the operation. It is not that the amount of the constituents of the blood necessary to life is so reduced in cases of severe hæmorrhage as to be incapable of sustaining the patient's vital processes, but rather that the bulk of fluid within his vessels is so diminished that the heart fails to contract on what remains. Increase to the bulk of fluid is

what is required, not an addition of red corpuscles, and this can be equally well obtained by the injection of saline fluid as by the transfusion of blood itself. When, therefore, death appears to be imminent from syncope and anæmia due to hæmorrhage, the injection of saline fluid may be tried with every expectation of good result. No complicated or special apparatus is required; a canula small enough to enter a vein, to which a length of rubber tubing can be attached, and a glass syringe, or a funnel, or a vessel to contain the fluid and from which it can be syphoned off, will be sufficient. The so-called "normal solution" may be used, but an equally efficacious fluid can be more rapidly prepared by adding a drachm of common salt to a pint of boiled water. This solution should be used at a temperature of 100.0° F., and usually from twenty to forty ounces will be sufficient, the amount depending on the effect produced on the pulse. All the parts of the injecting apparatus should be perfectly sterile, and great care is required to prevent the entrance of air into the veins; it should be seen that the solution is flowing steadily and without air-bubbles from the point of the canula before the latter is inserted into the vein. The mere injection of fluid into the rectum, whence it is rapidly absorbed, is also of marked advantage in the less urgent cases of this kind.

CHAPTER VI

GUNSHOT WOUNDS OF JOINTS

GUNSHOT wounds of joints are the class of injury which provide for the army surgeon in the field his greatest difficulties as regards both diagnosis and treatment. In pre-antiseptic days the treatment of a case of wound of a large joint admitted of no uncertainty or delay; the limb was amputated close above the seat of injury. But since treatment by the modern methods has proved that not in every instance of gunshot wound of a joint need the limb be removed, and, even more, that a large proportion of these cases recover with fairly useful limbs, and some of them with the functions of the joints hardly at all interfered with, amputation has had to give way to more conservative measures. Treatment by amputation was a simple matter; whereas the conservative treatment of gunshot injuries of joints, as well as that of the diaphyses of long bones, is one which requires, to bring it to a successful issue, all the energy, skill, and familiarity with modern surgical procedures which a surgeon is capable of possessing and devoting to the end in view. The difficulties of the conservative treatment of joint injuries are great anywhere; they are especially so in the field. Time and trouble have to be unstintingly expended in the constant care of such cases in order to attain the desired results, viz., the preservation of the life and limb of the patient; and the surgeon must always have before his mind the anxiety of knowing that, if he fails, his patient will, in many cases, be in a worse predicament as regards both than if he had resorted to the old treatment by amputation in the first instance.

Von Coler, in his report on the German experiments into the effects of the .314-inch calibre rifle, having first

detailed the injuries produced by it on the diaphyses of long bones, states that "the prospect is much more favourable in the case of injuries by bullets to the epiphyses . . . as well as in the case of hits on the joints;" and he adds: "If it be found that we may accept that wounds caused by small-bore bullets are, as a rule, aseptic, injuries to the joints will take a place amongst the most favourable hits on bones."

It is, no doubt, true that bullets of small diameter do not comminute the cancellous structure of the ends of long bones to the same extent as they do their shafts, and that the displacement of the fragments, when comminution occurs, is not so marked in the former as in the latter case. But to say that a gunshot wound of a joint by a small-bore bullet is a less serious injury than one of the diaphysis of a long bone—for it is with this the German report contrasts it—is to put forward a general statement which previous experience does not corroborate, and to suggest a view not held, so far as I can discover, by any other authority. Delorme, on the contrary, considers that joint injuries "are often followed by accidents nearly always serious, too frequently mortal; that they necessitate dangerous operative intervention, . . . and that the prognosis is almost as bad whether the bullet has merely grazed the bone or has caused comminuted fracture." From this statement it is evident that Delorme thinks that the danger in these cases, and their gravity, primarily depend on the wound of the joint capsule, though no one would suggest that he considers that the degree of comminution of the bones forming the joint is not a matter of great importance. Moreover, Von Coler begs the question to a large extent when he predicates an aseptic condition of the wound: to do so of any wound under treatment includes an inference of the patient's certain recovery, for no wound not immediately fatal, and which does not interfere with organs necessary to life, can be looked upon as otherwise than trivial if it runs an aseptic course. But what surgeon can guarantee asepticity in the wounds he treats? Do not accidents happen to wounds, by contamination with micro-

cocci, at the hands of the most careful surgeons; and are not joints especially prone to such infection? Septicity in a joint wound is a far more serious condition than a like accident in wounds of the shafts of long bones. When amputation was the rule of treatment for wounds of large joints, it was so because they all suppurated, and were almost certainly fatal from septic disease if otherwise treated, and it has only been since antiseptic methods came into vogue that conservative treatment has been possible. This statement applies with almost equal force in the treatment of gunshot fractures of the diaphyses.

As regards the choice between operative and conservative treatment for joint injuries in war hospitals, little or no change has resulted from the alterations which have taken place in small-arms. As just now mentioned, conservation can only be attempted under antiseptic methods. When, therefore, antiseptic dressing materials and appliances are not available, as may occasionally happen in campaigns, the old rules of treatment must be again followed, and amputations be practised in the cases in which the older surgeons found them the only means of saving life. The regulations in all European armies provide for a supply of the necessary antiseptic materials; but they may fail to be at hand when required, all the same.

Some of the difficulties in the treatment of gunshot injuries of joints by the army surgeon are dependent on the circumstances of the case, on, in fact, the circumstances under which the soldier receives his wound on the battle-field, and on the disadvantageous conditions of the treatment of such cases in field hospitals, which, we must remember, are merely temporary resting-places, and from which men have to be moved towards the base of operations at the earliest possible moment. Field hospitals soon become crowded with wounded men; their equipment and personnel are kept as low as possible; the work done in them is performed at high pressure; the patients are not treated in beds, but on the ground, the only bedding supplied being a blanket and a waterproof sheet for each patient. Serious cases treated under conditions such as these

present difficulties for the military surgeon which depend on the circumstances under which the wounds are received and treated, and from which the civil surgeon is quite free. The difficulties which enforced transport entails have been already many times referred to.

Speaking in general terms of these cases, wound of a joint may be caused in three ways—(*a*) by simple perforation of the synovial sac by wound of the synovial membrane only, without fracture of the bones; (*b*) by direct smashing of the articular ends of the bones; and (*c*) by fissures extending into the joint from a gunshot fracture of a long bone at some little distance from it.

The gravity of a gunshot wound of a joint, as regards the preservation of the limb, depends on three things—(1) on the degree of comminution of the bones; (2) on the amount of destruction of the soft parts about it; and (3) on the amount of interference with the blood and nerve supplies to the limb below: and, of the three, the gravity of these cases depends more on the interference with the blood and nerve supplies to the parts below by wound of the main vessels and nerves of the limb, than it does on comminution of the bone or destruction of the soft parts. In cases of gunshot wounds of joints, as well as in those of the diaphyses of long bones, complicated by laceration of the main vessels and nerves, amputation has been the general rule of treatment, and must continue to be so. Some two or three cases of wounds of the shoulder, thus complicated, were treated conservatively during the American War of the Rebellion, successfully so far as preservation of the limb was concerned; but the useless condition of the arm was so marked, some years later, that Otis condemned this method under the circumstances mentioned. Cases of joint wound where the large vessels and nerves are severed, treated conservatively with success, can only result in an atrophied and paralysed leg or arm, as the case may be, and the question whether primary amputation would not have been better for the patient is hardly an open one.

In former days a gunshot wound of a large joint was

almost always treated by amputation, so that the conservative treatment of these injuries is a comparatively new departure. Almost all the great wars, in which the older military surgeons gained their experience, occurred in the pre-antiseptic days; and even in the Franco-German and Russo-Turkish Wars only modified and tentative uses of antiseptics were made. The French used antiseptics during their war in Tonquin (1884), but no complete surgical history of the campaign has as yet been published, and the results of the newer methods used in that campaign are not fully available for our guidance. In our own expedition to Egypt antiseptic treatment was employed, but the wounded were comparatively few in number, and there are no statistics the study of which would teach us much with regard to gunshot wounds of joints; of the late Chilian War (1893) the same may be asserted. Therefore, even now, it may be said that not very much is known practically of what the results of the conservative treatment of joint injuries in war would be with modern methods thoroughly and accurately carried out from the first. But what is known warrants a most hopeful outlook, and enables us to lay down certain general rules regarding them, when treated conservatively and in strict accordance with the practice of Lister. Later on I shall refer more precisely to the treatment of particular joints.

In cases of simple wounds of the synovial membrane, conservative treatment should always be adopted, and will consist in careful washing and disinfection of the skin, irrigation with a weak sublimate solution, 1–4000 or 1–5000, antiseptic occlusion of the apertures, and immobilisation of the limb. The necessity for drainage in these simple cases is a moot-point. If no shreds of clothing or other foreign body have been carried in by the bullet, and if no irrigation has been carried out, or if the irrigation solution used has been an unirritating one and it has all been allowed to escape subsequently, drainage may not be required. But my own opinion is strongly in favour of a small drain during the first twenty-four hours. The joints in which simple wounds of the synovial sac are

most liable to occur are the shoulder, the hip, and the knee, and injury of this kind is difficult of certain diagnosis. But in joint cases where it becomes apparent that the bones are not implicated, it is better that the diagnosis should remain doubtful than that the wounds should be enlarged for exploration and examination, so long as the treatment is carried out on the lines which would be indicated if they were known to be for certain joint injuries.

In the second class of cases, where the articular ends of the bones are fractured, if the comminution be very slight, conservative treatment is also always to be tried. The procedures to be employed under these conditions are irrigation, the removal of *loose* splinters, antiseptic occlusion, drainage, and immobilisation of the limb.

In cases of comminuted, and even severely comminuted, fracture of the bones entering into the formation of a large joint, conservative treatment may still be attempted, when the condition of the soft parts about it, and of the large vessels and nerves, are not such as to distinctly indicate the necessity of primary amputation. This will, most probably, be the case when the injury is produced by a shell fragment. But small-arm bullets traversing the cancellous structure of bones do not, as a rule, cause such destruction of the soft parts, even at the exit side, as would necessitate amputation, notwithstanding that the comminution may be extensive. Indeed, it has already been pointed out that mere fragmentation of bone, other things being favourable, does not from its extent preclude attempts at conservation, but success in the treatment of such cases will altogether depend upon the care and efficacy with which antiseptic measures are employed.

Delorme[1] states that, with the means now at our disposal, in these cases "removal of splinters, irrigation, antiseptic dressings, and drainage of the joint, combined with immobilisation of the limb, will often suffice for cure, and should always be tried at first." It comes, in fact, to this, that, from a purely surgical point of view, *primary amputation* is indicated only when the principal vessels and nerves

[1] Vol. ii., p. 195.

are implicated in the wound. I say from a surgical point of view, because of the part the enforced transport of the wounded plays in warfare in compelling a resort to amputation when under different circumstances it need not be considered.

The necessity of moving from one hospital to another men on whom conservative treatment of gunshot wounds of the lower extremity is being carried out, only entails greater suffering and larger death-rates than amputation does; and after the greater suffering and the increased risk have been undergone, the chances are that secondary operations will be required, under more unfavourable conditions, to get rid of limbs preserved, so far, only at the cost of pain and danger to life. With wounds of the upper extremity, as already mentioned, the necessity of transport does not, to nearly so large an extent, contra-indicate attempts at conservation.

Conservative treatment of gunshot injuries of joints, and of bone injuries generally, is by no means a merely expectant or do-nothing method. It entails active carefulness directed towards strict asepsis in the wound and in the joint; it includes delicate operations for the removal of loose splinters of bone—by "loose splinters" are meant those completely, or almost completely, separated from the periosteum and the soft parts; it comprises also a thorough examination with a clean finger into the condition of the fractured bones, as well as irrigation, careful antiseptic dressing, and complete immobilisation in a fixed apparatus.

Judging from what has been said above, it might almost appear that conservation was the only procedure to be considered in the treatment of these cases. But I would ask the reader to remember that I have been speaking in the most general terms, and he will find later on, when I come to the consideration of individual joint injuries, that resection and amputation each has its place and its own indications.

The difficulties of diagnosis of joint wounds when the injuries are apparently slight in degree and not made clearly evident by comminution of the bones and crepitus,

are often very great; but no additional peril will be incurred by the patient from inaccuracy in this respect, if the advice already given be acted on, and all such doubtful cases are treated as joint injuries. But with wounds of the larger joints, as the shoulder, hip, and knee, especially the two latter, the obstacles experienced in determining the proper lines of treatment to give the patient even a fair chance of preserving his life or limb, or both, and in obtaining the means by which these procedures may be carried out in war hospitals generally, and in field hospitals in particular, are almost insurmountable.

When we remember that immobilisation is a portion of the treatment without which an injured joint can hardly recover, and that, in a large number of cases, extension and counter-extension may be almost as important; and when we further remember that the circumstances may be such that no consideration for the mere bodily welfare of the wounded can be permitted to interfere with the military rule for the evacuation of the field hospitals at the front, and that, live or die, patients must be passed back towards the base of operations, we shall be able to fully appreciate the difficulties which have to be met in the treatment of these injuries in the field otherwise than by primary amputation. To know that his patient must be moved next day, over bad roads in a jolting ambulance wagon, is not much encouragement to a surgeon to do an excision of a large joint, or to make an attempt to save a limb.

In no army in the world are the surgeons in so bad a plight in this matter of the enforced transport of the wounded, and of its effect on the treatment of wounds, as are the surgeons of the English army. In campaigns on the continent of Europe, one, at all events, of the combatants is in his native country, and every town and village supplies hospitals and attendants for the sick and wounded of the army, or buildings in which stationary field hospitals can be opened for their accommodation. Under these circumstances transport towards the base is not so imperatively necessary, becase the disabled men can be cared for almost where they fall, or, in any case, they may be left

behind protected by the Red Cross of the Geneva Convention. But in those countries in which the English army has, of later years, been engaged, and where our enemies know not Geneva or its Convention, the rule of sending the wounded towards the base as the army advanced has had to be accurately adhered to.

Sick and wounded men are not only so many inefficient units in an army; they are an actual impediment to its freedom of action, and must either be abandoned or become a check on its movements, unless otherwise disposed of. This necessity, therefore, of moving wounded men is a condition of field surgery which often determines for or against operation, and which often forces the army surgeon, and rightly so, to amputate a limb, rather than to do a resection or practise conservation—the condition which, in fact, decides for him what line of treatment he must adopt.

The gravity and importance of a gunshot wound of a joint of the lower extremity are, other things being equal, far greater than those of similar injuries in the upper extremity. In the American War of the Rebellion the mortality rates for all joint cases, under all methods of treatment, were as follows: hip, 84.7 per cent.; knee, 53.7 per cent.; ankle, 26.9 per cent.; shoulder, 34.9 per cent.; elbow, 19.4 per cent.; and wrist, 12.9 per cent.

Symptoms of Wound of a Joint.—The data on which gunshot wound of a joint may be based are, in most cases, very clear and simple. The situations of the bullet wounds, the direction of the bullet track, and the crepitus of the fractured bones, usually indicate the nature of the injury beyond the possibility of doubt. In cases in which the bones are not comminuted, and where uncertainty exists, the escape of synovia must be looked for, and the anatomical distribution of the synovial sac taken into consideration. When synovia is not seen, and doubt still remains, to err on the safe side will be the better plan; as already mentioned, the diagnosis should, under these circumstances, be one of joint injury, and the case should be treated in accordance with this view.

In forming our diagnosis we must remember that the modern bullet produces extensive fissuring of long bones, and consequently that a joint may be implicated in cases where the projectile has entered at a distance of several inches from it, by splitting of the bone from the point of impact into the joint. Cases of this nature are often impossible of recognition; but they run a satisfactory course, so far as the joint is concerned, if the neighbouring wound remains aseptic. On the other hand, suppuration and aseptic condition of the wound must inevitably be accompanied by a like complication in the joint, and a corresponding increase of the gravity of the case.

Gunshot Wounds of the Shoulder.—Of all wounds seen in war, about one-third are found to be of the upper extremity; and of all joint wounds, about 15 per cent. are of the shoulder. Amongst infantry soldiers it happens that the left shoulder is the more often hit; this naturally occurs from the position assumed by infantry in shooting, the left side being advanced and more exposed, while the right is in the opposite position and partially protected by the rifle. In cavalry soldiers the right side is more advanced and the right shoulder is more often the subject of gunshot injury. But the differences in this matter are very slight, and not of much practical importance.

All degrees of severity may be seen in these injuries, from merely capsular wounds, usually produced by small-arm bullets, to complete pulping of the bones of the joint and removal of the deltoid, or the greater part of it, by fragments of shell. Injuries of the latter kind may be complicated by fractures of the acromion and coracoid processes, of the scapula at the situation of the glenoid cavity, of the outer end of the clavicle, and by penetration of the chest by the bullet.

Wounds of the capsule of the shoulder joint unaccompanied by injury to the bones, may be caused, as Delorme points out, by a bullet passing from before backwards, or *vice versâ*, between the acromion process and the head of the humerus, and by opening the sheath of the long head of the biceps below the point at which it perforates the

capsule to leave the joint. There were seventy-two of these simple injuries recorded by Otis in the history of the American War, all of which were treated conservatively, with a death-rate of only 8 per cent., a ratio which clearly indicates the propriety of this method in such cases.

The amount of comminution which accompanies fracture of the bones entering into the formation of this joint varies considerably, and it depends on the velocity of the projectile, and on the part of the bone struck by it. The greater the velocity of the bullet the greater will, of course, be the degree of comminution produced by it. At

FIG. 34.

Part of head of humerus separated by a bullet striking above level of anatomical neck.—*Netley Museum.*

FIG. 35.

Part of head of humerus separated by a bullet striking about level of anatomical neck.—*Netley Museum.*

a low rate, a mere tunnel may be punched through the cancellated tissue.

A bullet travelling at a medium rate, and merely grazing the head of the humerus, above the anatomical neck, will probably only cut a groove through the cartilage and cancellous structure of the head of the bone, causing little or no fragmentation or fissuring, and the fissures which may occur will probably stop at the anatomical neck. If the point of impact be at the anatomical neck, the head of the humerus, above this line, is usually quite separated

from the shaft, and it may be broken into two or three pieces, while fissures may extend into the surgical neck, but without much tearing of the periosteum over them (figs. 34, 35, 36, 37, and 38). The actual head of the bone is in this case frequently to be found loose within the cavity of the joint and completely cut off from its blood supply.

When the bullet strikes on the surgical neck, the comminution of the bone, and the fissuring into the head and down the shaft, may be very extensive; but, although the displacement of some of the fragments may be consider-

FIG. 36.

Result of bullet striking anatomical neck of humerus.—*Netley Museum.*

FIG. 37.

Result of bullet striking anatomical neck of humerus. —*Netley Museum.*

able in the vicinity of the track of the bullet, the upper fragment, as a whole, does not always so lose its adherence to the soft parts and to its periosteum as to be deprived of its blood supply, and under proper treatment the fragments may consolidate, and recovery take place (figs. 39, 40, and 41). In a word, a graze of the head of the humerus causes fissures which usually cease at the anatomical neck;

whereas when the latter situation itself is hit, a fissure usually extends all round, separating the head of the bone completely: while a bullet striking the surgical neck causes much greater destruction, separating the head from the shaft, but does not so frequently cut off the blood supply of the upper fragment. Partial or complete dislocation of the head of the humerus has also been recorded by some surgeons, by Chenu amongst others, as a complication of gunshot wound of the shoulder.

Treatment.—In cases where the bones of the joint are not implicated, but simple capsular wound is certain from the escape of synovia, or suspected on account of the situation of the entrance and exit wounds, no examination with instruments or the finger need be made. No further indication for treatment can be arrived at by extreme accuracy of diagnosis, because the method to be employed in both cases is the same: the case should be looked upon as one of wound of the joint. Even in these doubtful cases, movements of the arm to elicit crepitus, or to ascertain how much of the normal motion of the joint remains, should be made, if at all, with the greatest caution, lest further damage be produced by them. The wounds and the skin surface around them should be thoroughly washed and asepticised; iodoform should be dusted on the skin wounds, and a dry gauze and alembroth wool dressing applied. An ample supply of antiseptic wool should also be placed in the axilla, and between the arm and the side of the chest. No splints are required; the hand should be placed across the front of the chest, in the position employed in the treatment of a fractured clavicle, and the in-

FIG. 38.
Result of bullet striking anatomical neck of humerus.—*Netley Museum.*

jured arm and forearm bandaged to the body by means of a wide roller. Almost the only danger in these cases is that of suppuration in the joint; when this is avoided they heal rapidly, and no interference with the movements of the limb remains.

The treatment of those cases of wound of the shoulder in which fractures of the articular ends of the bones take place, as, indeed, the treatment of similar injuries of all joints, has to be considered under the heads of (*a*) conservative treatment, (*b*) amputation, and (*c*) excision.

Fig. 39.
Result of bullet striking surgical neck of humerus.—*Netley Museum.*

Fig. 40.
Result of bullet striking close below anatomical neck of humerus.—*Netley Museum.*

All wounds of the upper extremity are peculiarly amenable to conservative treatment, when compared with those of the lower limb, because in them immobilisation, and even extension, can be carried out although the patients have to be moved. Wounds of the shoulder form no exception to the truth of this statement; on the con-

trary, they are a class of joint injury in which this method has been especially successful.

It may *almost* be said that in wounds of the shoulder joint no amount of shattering of bone, provided that the great vessels and nerves remain intact, precludes attempts at conservation. The importance of the forearm and hand, if any of their functions be retained, warrants a slight risk being run for their preservation. The extra risk referred to is the slightly increased ratio of mortality which follows the secondary operations of amputation and excision rendered necessary by the failure of conservative treatment.

If the conservative treatment of these cases fails, a secondary excision may be performed; this, if successful, only

FIG. 41.
Result of bullet on surgical neck of humerus.—*Netley Museum.*

shortens the humerus, and successful conservative treatment can, at the worst, only anchylose the joint; but a shortened humerus or a stiff shoulder joint is as nothing compared to the loss of the forearm and hand entailed by amputation. Moreover, the mortality following primary amputation is nearly as great as that after conservative treatment, and not much less than that following primary resection, while the mortality of primary resection is greater than that of conservation.

In those cases in which the bones of the joint are fractured, a complete examination should be made. The condition of the limb below, as regards circulation and sen-

sibility, should be ascertained, for the treatment to be pursued depends, to a large extent, on whether or not the large vessels and nerves are wounded. An exploration, under an anæsthetic, should be made with the finger, in order to learn the condition of the fractured bones as regards comminution, displacement of fragments, the presence of loose splinters, and for the removal of the latter. In making this exploration the finger should, if possible, only be introduced once: it should not be removed from the wound until the surgeon considers that he understands exactly the nature of the case, and that his diagnosis is sufficiently accurate to warrant him in determining his line of treatment: one introduction of the finger should be made to suffice for ascertaining all the data on which the diagnosis and treatment of all joint cases must be based.

The cases, besides those of simple capsular wound already referred to, in which conservative treatment may be attempted, are those in which the bullet has traversed the joint or its immediate vicinity, without causing much comminution of the bone—where, in fact, the injury to the humerus is slight; and fractures of the glenoid cavity, of the acromion and coracoid processes, without injury to the humerus, are also suitable for this method.

The procedures to be carried out are the removal of splinters which are so loose, and detached from the soft parts, as to be capable of being easily disengaged without the use of cutting instruments; the replacement, as far as is possible, of such fragments as are merely bent away at one end from the main portion of the bones to which they belong; the thorough irrigation of the wound with a warm antiseptic solution; the provision of means of drainage; and the immobilisation of the limb and joint.

The removal of splinters is a delicate and sometimes a difficult operation. Delorme refers to it as a "true arthrectomy" when splinters have to be removed from the joint cavity. One or sometimes both of the wounds must be enlarged, occasionally by long incisions, and the pieces of bone gently disengaged from the soft parts in which they may be entangled; the finger and a forceps are the best

means to employ for this purpose. Large fragments seldom require removal; and, unless quite detached, no fragment, large or small, should be subjected to this treatment; with an aseptic condition of the wound they may be expected to consolidate and unite, although probably with the formation of a large amount of callus.

The irrigation should be made with a solution of carbolic acid not stronger than 2 per cent., or with one of corrosive sublimate of a strength of 1 in 4000; and what-

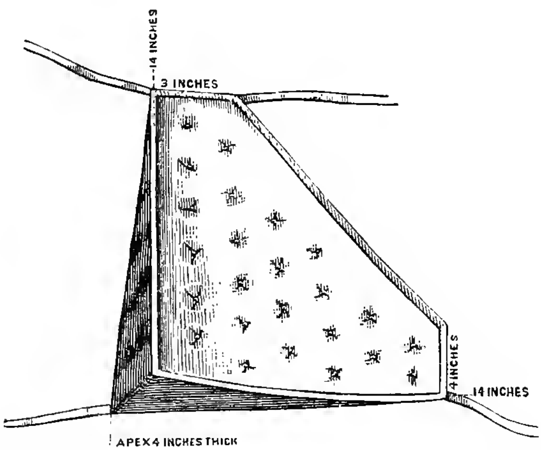


FIG. 42.
Stromeyer's Cushion.

ever apparatus be used, syringe or irrigator, care should be taken that the joint is not overdistended by the fluid, and that a free exit is provided for it. The common irrigating apparatus, to the rubber tube of which is attached a glass-tube nozzle, is more effective than the syringe. Drainage should be maintained by the usual means for at least twenty-four or forty-eight hours. The dressing should be composed of dry gauze and an ample amount of alembroth wool.

Immobilisation of the joint must be effected by means of a hollow wooden splint on the outer and back part of the

arm, extending from the elbow to above the shoulder; or a gutta-percha splint may be moulded over the joint and to outer and back surfaces of the arm. When either of these means are used, the axilla and inner side of the arm must be well padded with wool, and the arm and forearm bandaged to the chest.

One of the best means for the purpose of fixing the arm and shoulder joint in cases of gunshot fracture is Stromeyer's cushion (fig. 42). It is so constructed as to fill up the space between the elbow and the side of the chest when the arm is hanging vertically down and the forearm flexed at a right angle. It is triangular in shape, the corner at which the elbow rests being about 4 inches thick, while the other two corners are only about ¼ inch in thickness. MacCormac states that Stromeyer explained to him his reason for inventing the apparatus—that its use did not necessitate constricting bandages on the arm, as "there is a fatal facility for gangrene to occur if any tight bandaging or splints are applied to the fractured upper limb." It is a useful immobilisation apparatus if the patient be in bed, but it is especially adapted for this purpose if he have to be moved, when the cushion and the arm should be supported in a sling.

Chauvel and Nimier[1] say, "We should always try to save the arm, except in cases where amputation is evidently necessary on account of the destruction of the main vessels and nerves of the limb." They advise that in cases to be treated conservatively we should not attempt to remove the splinters, because this not only entails long incisions down to the bone, thus increasing the size of the wound, but it also tends to the removal of periosteum, thus setting free pieces of bone that were, in a certain measure, adherent; it causes great additional damage, and even then the most dangerous fissures may remain unrecognised. In the Tonquin Expedition "they gave up the systematic removal of splinters, because, owing to the antiseptic treatment employed, they obtained union of pieces of bone completely detached." This experience

[1] *Traité de Chirurgie d'Armée.*

exceptional; fragments of bone "completely detached" will, if left in a wound, most frequently act as foreign bodies, cause inflammation and suppuration, and they will most probably require removal later on in the course of the case.

The dressings of these cases, once the drains have been removed, should be as infrequent as possible, pain and rise of temperature being the only indications for their renewal under a week.

Should suppuration develop and infection of the wound occur, the joint should be laid open by an anterior vertical incision, disinfected by means of the stronger antiseptic solutions, and washed out twice a day with the weaker ones.

In some few cases of wound of the shoulder, treated by conservation, perfect movement has been preserved in the joint; a larger proportion preserve some movement, the restriction being greatest towards abduction; and between 50 per cent. and 60 per cent. end in ankylosis, partial or complete. This method of treatment by conservation is troublesome, and the convalescence tedious, but the functions of the limb are better after it than they are after primary excision.

Excision.—Primary excision of the shoulder has proved a most excellent operation in military practice in those cases in which, while the large vessels and nerves remained intact, and the soft parts were not too extensively lacerated, the bones of the joint, and more especially the head and upper portion of the shaft of the humerus, were found so severely comminuted as to make it apparent that consolidation of the fragments was impossible, or improbable, under conservative treatment. The operation, when done for bullet injury, is most often a partial excision, the upper end of the humerus only being removed; but the complete operation, including the glenoid cavity, or portions of it, is frequently required, and gives satisfactory results.

The excision of this joint in the field was strongly advocated by Percy; it has been practised by Langenbeck, Stromeyer, Schwartz, Legouest, Baudens, &c.

Baudens, speaking of cases treated before conservative treatment had given such good results as are now obtained

under antiseptics, goes so far as to say that "resection of the head of the humerus should be performed whenever the shoulder is opened by a bullet," but a dictum of this general character is not now permissible. Cases suitable for the three methods of treatment, by conservation, excision, and amputation, are, theoretically, quite distinct from each other, the only difficulty being to decide, practically, the amount of damage which properly places individual cases in one or other of the two first categories.

The operation was performed in the Crimean, Italian, French, and German campaigns, as well as in the American War and in our own smaller wars. The indications for primary excision of the shoulder are—(1) fragmentation and separation of the head of the humerus at or above the anatomical neck by a bullet striking at the latter situation; (2) comminution of the upper end of the bone by a bullet striking on the surgical neck and producing complete separation of the head from the shaft; and (3) fracture with comminution and lodgment of a bullet in the head of the bone, the extraction of which is found to be impracticable.

As regards the time at which the operation should be undertaken, it may be laid down in general terms that the sooner it is performed after the receipt of the wound the better, once the patient has sufficiently recovered to be able to bear it. As little of the shaft of the humerus as possible should be removed, while, at the same time, care is taken that all the comminution and loose splinters are taken away. The probability of "flail-joint" is in direct proportion to the extent of the humerus removed; but, to show that large portions of it may be excised with satisfactory result, I may mention that Surgeon W. D. Bliss removed six inches of the head and shaft for shell wound of the shoulder in the American War, the man recovering with a most useful limb: "the movements of the forearm and hand were not at all impaired," and "the patient could put his hand on the top of his head and lift a weight of 200 lbs. with the injured limb";[1] all the motions of the joint were free except abduction.

[1] Otis.

The arm is no doubt more useful after successful conservative treatment, but this does not detract from the excellence of primary excision, because the latter method should only be employed when the former is inapplicable.

Professor Hannover, of Copenhagen, writing of the results of the excisions done by the Prussian surgeons in the Dano-Prussian War of 1864, contends that lapse of time brings no improvement in the uses of the limbs after excision of the shoulder; rather, indeed, that they progressively deteriorate.

That Hannover's opinion is incorrect there is good evidence to believe. No doubt, even though the wound may heal quickly, recovery of the power of free movement is not rapidly regained; but Dr. Otis, in America, and Dr. Gurlt, in Germany, who probably have had more opportunity of judging of the after effects of operations on joints than any other surgeons in the world, are quite clear in the statements of their experience. Otis had, besides cases known to himself personally, the reports of the examiners of pensioners who were wounded in the War of the Rebellion. He states that "Hannover is undoubtedly in error in contending that remote amelioration after excisions for injury rarely or never occurs. I have, under personal observation, more than a score of pensioners in whom progressive improvement has continued for ten or twelve years after excision at the shoulder for shot fracture, and, in several of them, all the functions of the upper arm, except abduction, have become nearly perfect. Indeed, the testimony on this point is cumulative." Gurlt, who has made an exhaustive research into the ultimate condition of patients subjected to excisions for gunshots since the wars of the last century, says, "Fortunately, we now know that the results (of excisions of the shoulder) have greatly improved after the limbs have been for some years in constant use."

The Operation of Primary Excision of the shoulder should be performed through an incision on the anterior and outer surface of the joint, commencing just below the coracoid process, and extending downwards for four or

five inches, or as far as may be required, parallel with the fibres of the deltoid, no regard being paid to the situations of the entrance or exit wounds. As little injury as possible should be done to the deltoid muscle, its fibres being split apart rather than cut, and interference with the circumflex nerve must be carefully avoided. If the long head of the biceps has escaped section by the bullet, it must be preserved intact; the attachments of the muscles to both tuberosities should be cleared from the bone with the periosteum as far as possible, and without breaking down their intimate connection with the capsule of the joint. As in these cases the upper fragment will be found quite detached from the shaft of the bone, the saw will only be required to remove the splintered end of the lower fragment. If the glenoid cavity and neck of the scapula be found implicated in the injury, such portions of them as are loose, or have but little adhesion, should also be removed. The joint should be well irrigated with a weak antiseptic solution, drainage should be provided for through one of the wounds or at the lower end of the incision, and the edges of the latter brought accurately together with a continuous horse-hair or silkworm gut suture. Dry gauze and wool dressings should be applied, and the same means employed for immobilisation as were recommended for cases treated conservatively.

The arm requires to be well supported at the elbow, in order to bring the upper end of the humerus as close as possible to the articular portion of the scapula, and to allow of the divided muscles becoming attached as high as possible. The elbow, wrist, and finger joints must be constantly treated by passive motion to prevent stiffness occurring in them, and the new joint must be passively exercised at an early date. The greater the attention devoted to passive motion, massage, and the use of electricity to all the muscles of the limb, the better will probably be the degree of mobility of the joint, and the more perfectly will the functions of the arm be recovered.

Intermediate Excision of the shoulder is an operation which only requires mention in order to recommend the

avoidance of its employment in war hospitals. If the first twenty-four or, at most, forty-eight hours have been allowed to pass without a primary excision having been done, and operation be deemed necessary, then it will be better to await the disappearance of the consecutive inflammation of the intermediary period, and perform a secondary excision later on. Intermediate operations of all kinds are more fatal than are the primary and secondary operations; in the American War they gave an increased mortality of 10 per cent., at least, over those of the other periods. The causes of death from intermediate excision are gangrene, pyæmia, secondary hæmorrhage, septic fever, and exhaustion. Osteitis and osteomyelitis are also common sequelæ of the intermediate operation.

Secondary Excision of the shoulder gave very good results during the American War, where the mortality following it was less than that of the primary operation; but in other wars, while the operation still proved a most valuable one, the reverse was the case.

Löffler says, "It is undoubtedly the duty of the surgeon, in cases of shot wound of the shoulder, to excise the joint during the first forty-eight hours. Statistics are unnecessary to convince the field surgeon of the advantages of primary excision." Schwartz, writing of his experience in the Schleswig-Holstein Campaign, says, "All excisions (of the shoulder) should be primary; the secondary should only be performed when the injury was overlooked in the first place, or if there was not time or opportunity to resect during the first twenty-four hours." Macleod[1] was of opinion that "primary excisions were much more successful than those done at a later period, both as regards final results and duration of convalescence." MacCormac, and, indeed, the majority of military surgeons, hold similar views. From the nature of the case it must be that secondary operations are, in most instances, likely to be followed by larger death-rates than primary ones, because the conditions which call for them are those which will also place the patients in a

[1] "Notes on the Surgery of the Crimea."

less favourable position to recover from any surgical interference.

Secondary excision of the joint is indicated in cases in which conservative treatment has failed from infection of the wound, and when prolonged suppuration, accompanied by osteitis and necrosis, is wearing the patient out, and death is almost certain unless the causes of these conditions be removed. In these cases, also, the anterior straight incision is usually the best, but in some cases enlargement of one of the wounds may be employed. The wound should be completely disinfected by means of one of the strong antiseptic solutions, and free drainage be provided for and persevered in until discharge has nearly ceased. The after treatment and the means to be used for immobilisation are the same as those found suitable for primary cases.

Amputation at the shoulder joint is rendered necessary rather by the amount of destruction of soft parts, and especially by the implication of the main vessels and nerves of the limb, than by the degree of comminution of the bones entering into the formation of the joint. Severe comminution of bone does not call for primary amputation; conservation and excision may still be indicated. But when, together with a gunshot fracture of the joint, the large vessels and nerves are wounded, little hope can be entertained of saving the patient's life unless amputation be performed. Moreover, even if that little hope be realised, and conservative treatment be successfully carried out so far as the preservation of the limb is concerned, the uselessness of the atrophied and paralysed arm saved under these conditions has already been pointed out. Primary amputation at the shoulder joint is therefore necessary in all cases of gunshot fracture of the joint, or of the surgical neck of the humerus, complicated by destruction of the main vessels and nerves of the limb. It may also be indicated when, although the vessels and nerves are intact, the wound of the shoulder is further complicated by other extensive gunshots of the elbow or wrist on the same side.

Sir William MacCormac excised the shoulder and elbow joints on the same side in the case of a man of the Chasseurs d'Afrique, during the war of 1870–71, the patient recovering almost perfect use of the limb.

But this case is almost unique. The extra risk incurred by patients whose shoulder wounds are treated by conservation or excision, rather than by primary amputation, is only warranted by a reasonable probability of preserving a useful forearm and hand; and when the elbow or wrist (especially the latter) is also wounded, the chances are greatly against this favourable result. Cases of this nature should, therefore, usually be treated by primary amputation at the shoulder joint.

Secondary Amputation at the shoulder may be rendered necessary by secondary hæmorrhage which is not amenable to other means of treatment; by the supervention of gangrene or osteomyelitis; by failure of consolidation of the fractured bones; by necrosis of the humerus or of a large portion of it; by long-continued suppuration in the joint and in the wound, and when the patient is being worn out by discharges and high temperature, and is certain, if he does not die, to be left with a wasted and useless limb. These are the conditions under which the secondary operation is usually required.

The Method of amputating at the shoulder joint in gunshot cases must be varied according to the condition of the soft parts as regards laceration, and the surgeon must be prepared to make the best use he can of the soft parts he finds uninjured for the formation of flaps and covering for the stump. Transfixion operations are not expedient in cases where the continuity of the bone is lost near the head, in consequence of the loss of the power of manipulating the humerus which is so necessary in these methods. The oval method (Spence's modification of Larrey's operation) is the best to use in gunshot cases. A straight incision is made from the tip of the coracoid process to the insertion of the deltoid, similar to that used for excision, which operation may then be done if, on examination of the joint, the degree of fracture indicates this procedure.

If not, an oval incision down to the muscles is made at the end of the straight cut, care being taken not to wound the vessels on the inner side. The skin flaps are then dissected up, commencing with the outer one, the head of the bone displaced from the glenoid cavity; the knife is inserted between the bone and the muscles on the inner side of the arm, and, being kept close to the humerus, the uncut tissues on that side are severed. The vessels are cut in the last portion of the incision, and should be compressed in the inner flap by the hands of an assistant as the knife makes its way out. The axillary vein will require ligature as well as the artery. The wound should be thoroughly irrigated, and drainage provided for during the first twenty-four hours.

Concluding Remarks.—To sum up, then, this matter of the treatment of gunshot injuries of the shoulder: in a certain number of these cases a moment's inspection and examination convinces the surgeon that there is no possibility of saving the limb, and that primary amputation is the only resource. But in those others in which the question of primary amputation need not be entertained, all available statistics of mortality after injury to this joint point towards conservative treatment rather than to primary excision. For if conservative treatment succeed, the functions of the forearm and hand, if properly attended to in the manner already suggested, are better after it than after primary excision; and if it fail, we still have secondary excision and secondary amputation to fall back upon. But the mortality following primary excision in the American War was 31 per cent., and after secondary excision 29.3 per cent.; so that if we have to do a secondary excision, we have lost nothing in not having done a primary one. Then, again, the mortality after secondary amputation in the same war was 28.7 per cent.; and if the case come to this procedure, after failure of conservative treatment, this mortality of 28.7 per cent. has to be compared with one of 31 per cent., which was that following primary excision, which was the alternative operation. Judging, therefore, from the statistics of the American War,

the statement would appear to be borne out that, setting aside those cases in which primary amputation is clearly indicated, conservative treatment gives better results, both as regards the utility of the limb and the ratios of mortality, than does the alternative treatment by primary excision. The following table gives the death-rates following the different methods of treatment observed in the American War:—

Conservative and Operative Treatment of Gunshots of the Shoulder (Otis).

Conservative treatment..........	27.5	per cent.	mortality.
Primary amputation at shoulder .	24.1	"	"
Intermediate " "	45.8	"	"
Secondary " "	28.7	"	"
Primary excision of joint........	31.06	"	"
Intermediate " "	46.4	"	"
Secondary " "	29.3	"	"

The mortality rate given in the above table for conservative treatment of shoulder cases, as compared with those resulting from primary and secondary excision, is exceptionally low—less, in fact, than has been recorded for any other war. In the Schleswig-Holstein and in the Russo-Turkish wars it was considerably higher. But statistics of mortality are not the only things the surgeon has to consider in determining his treatment of a given case. If they were so, every gunshot of the shoulder would be properly treated by primary amputation, for by this method the death-rates following these injuries would be greatly reduced. But the importance of the forearm and hand in the economy of the body is so great that the surgeon, both from his own and the patient's point of view, is fully justified in dividing wounds of the shoulder into the three classes—viz., those in which conservation, amputation, or excision is indicated; and the extent of injury which places cases in one or other of these three categories is fairly well defined.

Conservative treatment aims at a freely movable joint as its best result; but even if motion be lost, or greatly impaired, the utility of the arm may still be very great.

Moreover, it is always possible to regain motion after ankylosis by a secondary excision of the head of the humerus. Even a certainty of ankylosis would, by no means, contra-indicate conservation. The evidence we have available, so far, of the results of conservative treatment has been derived from cases the large majority of which were treated without the use of antiseptics; nevertheless it is encouraging. But in future wars the advantages to be obtained by it must be still more valuable.

The results of excision of the shoulder are also satisfactory, both as regards the life of the patient and the utility of the limb, the primary operation giving a smaller death-rate than those done at the later periods. Otis points out that the combined mortalities following all "the consecutive operations exceeded that of the primary by more than 10 per cent.," but the fatality following true secondary excisions was less than that of the primary by 2.3 per cent. The utility of the limb after excision, if the treatment of the muscles and of the other joints are properly attended to during convalescence, is usually very great.

Delorme alludes to the great advantage of the anterior incision for this operation in preserving the action of the deltoid muscle, interference with which is usually the cause of indifferent results following excision of the shoulder, and to the paralytic condition which is certain to result from interference with the circumflex nerve. The sub-periosteal method should be employed as far as possible. A flail-like arm is the more likely to follow excision, as the extent of bone removed below the anatomical neck is great; but the possibility of flail joint must not be looked upon as a contra-indication for excision. According to Gurlt, the final results of excision in the Franco-German War were "good" in 44 per cent., "moderate" in 48 per cent., and "bad" in only 8 per cent.

Gunshot Wounds of the Elbow.

Gunshot wounds of the elbow joint are eminently suitable for conservative treatment, and this method should be tried in all such cases, except those in which the crushing

of the bones and the destruction of the soft parts are such that nothing short of amputation or excision can be considered. During the American War the results obtained, even without antiseptics, were extremely good when compared with those resulting from excision or amputation, the death-rate of the former being less than half those following the two operative procedures. But it should be remembered that, in statistics, conservative treatment never gets the discredit of the real death-rate, properly speaking, due to it; because, if it fails to cure, secondary operations are done in a large number of cases, and when fatal results ensue, the deaths are necessarily put down to the operation rather than to the method used at the beginning of the case: whereas, possibly, had a primary amputation or excision been performed, death might not have followed. Again, all the very slight cases are treated conservatively, and naturally these have a low death-rate.

Conservation.—A large proportion of wounds of the elbow resulting from rifle-bullets will be found suitable for treatment by conservative methods. Simple wounds of the synovial membrane should be so treated, as a matter of course. Fractures unaccompanied by much splintering and comminution of one or other of the condyles of the humerus or of its trochlear surface; similar injuries of the olecranon and of the radius; and even cases in which the ends of all the bones entering into the formation of the joint are implicated to a slight degree are all suitable for a trial of conservative treatment.

The great aim of conservative treatment should be to obtain a movable joint, and to so treat the joint, as to position, that, if this desirable end be not achieved, ankylosis may take place at the best angle as regards the after utility of the limb. A small percentage of cases treated without operation do retain complete or partial movement in the joint, but the large majority recover with true bony ankylosis. Otis mentions three cases of recovery with good motion in the joint. Dominick states that in his researches into the results of conservative treatment of elbow cases in the Franco-German War, he found 83 per

cent. of ankylosed joints, and 6 per cent. in which good motion remained. Audet,[1] out of a large number of cases, found only 2.5 per cent. with good motion retained. Ankylosis takes place in almost all the cases in which the articular surfaces of the bones are implicated, whereas cases of simple wound of the synovial membrane should recover with considerable motion if suppuration in the joint be avoided. Some motion in pronation and supination may be retained in elbow joints, otherwise ankylosed, when the head of the radius and its articulating surface on the humerus have escaped injury.[2]

The cases in which a movable joint is retained are so exceptional that ankylosis may be looked upon as almost the best result to be expected in elbow cases treated conservatively; and this can hardly be considered good. Ankylosis at the elbow is even a more disabling condition than a similar result in the shoulder. Otis therefore concludes that the results obtained in the American War, good as they certainly were as regards mortality, were not very satisfactory as regards other points. "Amongst the survivors there were many examples of chronic arthritis, with caries and persistent fistulæ and exfoliations; many instances of paralysis with shrunken, wasted limbs, and contracted, powerless hands. The known instances of recovery with preservation of the functions of the joint were very few; and those with ankylosis in a favourable position, and with freedom from disease about the joint and good use of the forearm and hand, were not numerous."

With modern treatment of these cases better results may with certainty be looked for. Prevention of septicity in cases of simple synovial wounds may be relied on to leave motion unimpaired. In cases of fracture of the joint treated conservatively, although aseptic methods may not so frequently prevent ankylosis, they may be expected to do so when the comminution is slight; and in any case they will reduce the number of cases in which septic complications occur, and the number of those requiring secondary amputations and excisions. Delorme insists on

[1] *Manuel de Chirurgie d'Armée.* [2] Otis.

the advantages of conservation in all but the most extensive injuries to the bones of the joint. Langenbeck remarks: "The numerous cases of the last wars indicate that there must be many shot injuries of the elbow joint where resection can be avoided." Rupprecht observes: "It is easy, after a complete shot comminution of the elbow, to decide on amputation, or, if the splintering does not extend too far, to resort to primary resection (which I prefer to delayed operations); nevertheless it is to be deplored that the advantages of resection should ever be so enthusiastically regarded as to lead to the danger that the conservative treatment of such injuries should be liable to exist only in name."

The Means to be Employed to successfully carry out the conservative treatment of elbow cases are fairly easy of attainment; any fixing apparatus which keeps the joint at complete rest, while the site of the wounds is easy of access for the purpose of re-dressing without removing it, is suitable. The surgeon must always keep before his mind the fact that ankylosis is the rule where the bones are comminuted; he must therefore carefully attend to the relative position of the forearm and hand to the humerus, so that, when ankylosis does occur, the former may be so placed as to be of the greatest possible utility to the patient under the circumstances. The forearm should be flexed on the arm to a right angle, and the hand should be in the position half-way between pronation and supination, the thumb pointing upwards. This position of the forearm should be maintained from first to last in the treatment of the case.

Cases of simple wound of the synovial membrane, and cases in which this is suspected, need not be examined with probes or fingers. The wounds of entrance and exit, and the skin surface around them for some considerable distance, should be thoroughly asepticised and washed, and dry gauze and wool dressings applied. A splint fixing the arm and forearm in a slightly flexed position, and extending to the points of the fingers, should be applied to the inner side of the limb, and slung to a support above

the bed or laid on pillows, the former method being the more comfortable for the patient. The right-angle position is not required in these cases. If no inflammatory action takes place—and none should take place if the preliminary disinfection has been effectively carried out—the degree of flexion of the forearm should be varied at each dressing, that is about every six days; and later on, when the wounds are nearly healed, or considerably before that if they are extensive, passive motion should be gently practised.

In the more severe cases, where comminuted fracture has occurred, thorough exploration of the joint is necessary to ascertain the degree and extent of the injury, and for the removal of loose splinters and fragments of bone. The joint and the wounds should be well irrigated with a warm solution of perchloride of mercury, 1–4000, or of 1–40 carbolic acid, and drainage provided for during the first day or two, after which it may be removed if the case proceeds satisfactorily: the right-angle position must be maintained in these cases.

If infection of the joint and suppuration should occur, a free incision should be made into the joint on the outer and back part of the elbow, through which disinfection may be performed, splinters which have become loose removed, and drainage maintained. If, notwithstanding this treatment, suppuration continues, a secondary excision must be performed.

Excision of the Elbow.—This operation had but little repute in military practice until the successes of Langenbeck and Stromeyer in the Schleswig-Holstein Campaign of 1848 were reported by Esmarch. Syme[1] had already proved the excellence of the operation for disease, but for gunshot injuries it had been but little used. Since the war above referred to, it has come more and more into favour with army surgeons, so that in 1851 we find Esmarch putting forward as his opinion that "in all injuries of this kind (gunshots of the elbow) it is the duty of the surgeon to assist nature by an operation." Stromeyer

[1] "Treatise on the Excision of Diseased Joints," &c.

is equally decided in his view: "In *all cases* where I recognised a shot injury of the bones of the elbow joint, I did not hesitate to allow the resection of the joint to be performed." While statements of this kind made by such authorities are valuable in enabling surgeons to attain a right estimate of excision in cases requiring it, they must not be allowed to make us overlook the good results to be obtained by conservative treatment, and the low death-rate following it. But whether conservative treatment or excision shall be selected for a given case cannot be determined by death-rates; the indications for each are different: a case presenting the indications for excision is not suitable for conservative treatment, and one in which hopes of recovery with a useful joint can be entertained with this method, does not require a primary excision, although a secondary operation may eventually be necessary. As regards saving of life, Otis does not report very favourably of excision of the elbow as observed in the American War. He says:[1] "In military practice in this country, however, a brilliant success can hardly be claimed for the operation. Although the point is open to argument, I fear that the substitution of this resection for amputation effected no saving of life." But he admits that others have had better reason to be satisfied with it. In the English army in the Crimea, seventeen excisions were performed with only two deaths, and five partial operations, all of which were successful. The mortality of excision of the elbow on the German side (war of 1870–71) was 26 per cent.,[2] while amongst the French, according to Chenu, it was about three times as fatal; but this ill success was due to causes beyond the control of the French medical service, not to any defect inherent in the operation.

The cases which require primary excision are those which, on examination with the finger in the joint, are considered to be of too comminuted a character to warrant purely conservative treatment; cases in which, when the loose splinters have been removed, it is found that the remaining ends of the bones are in too ragged and uneven

[1] Part II., Surgical Volume, p. 903. [2] Sédillot.

a condition to be left, and it is necessary to smooth off the sharp points projecting into the joint, while at the same time the large vessels and nerves are uninjured. Some cases of excision have been successful when the brachial has had to be ligatured; but good results are so exceptional under these circumstances that it may be considered as a strong contra-indication of the procedure. Fractures, also, where the fragmentation and crushing of the bones extend for a considerable distance from the joint, are unsuitable for excision, and should be treated by amputation.

The question of whether partial or complete resection of the elbow is the more favourable procedure has been much debated. When only some of the bones are fractured should the ends of these alone be excised, or should the articular surfaces of *all* the bones be removed or not? No complete answer can as yet be given.

Mobility in the joint is the end aimed at in excisions; but ankylosis has hitherto been much more frequent after partial than after complete operations, while the latter are more liable to be followed by flail joint than the former. Of the two conditions, flail joint is the greater disability; but ankylosis, to be a lesser inconvenience, must be at the correct angle. In either case, unless the movements of the wrist and finger joints are preserved, amputation would have been preferable. Löffler is of opinion that we should appreciate more highly recovery from excision of the elbow with ankylosis, and that sometimes this result is one to be desired. Schüller and Esmarch consider that partial excisions are inadvisable; while Delorme is of opinion that we should only interfere with the injured bones.

The complete removal of the articulation when only some of the bones are injured, would seem to be an unnecessary proceeding; but no doubt partial operations require that careful attention be given to passive movements of the joint during convalescence, to prevent ankylosis. My own experience is in favour of removing only what is damaged, as two cases in which this was done for gunshot injuries recovered with a good amount of motion in the joints. Gurlt's statistics for the Franco-German War give the re-

sults as "good" in 29 per cent. of the cases in which the elbow was excised, "moderate" in 53 per cent., and "bad" in 17 per cent. According to the same authority, the mortality was less after excision than after primary amputation, being as 18.3 per cent. is to 23 per cent. Partial excision did not give as good "end-results" as the complete; "the convalescence was more tedious, and the functions of the joint not so well recovered." The end-results in the American War, according to Otis, were that "a fair proportion retained a fair amount of control over the uses of the forearm and hand; a smaller number had very serviceable limbs, and in a few instances the usefulness of the limbs was hardly at all impaired."

As regards the period at which the operation should be performed, excision of the elbow joint forms no exception to the general rule, that primary operations for gunshot injuries are to be preferred to secondary ones. Billroth, in 1872, considered the primary operation safer as regards life, but was doubtful regarding any advantage to be obtained by it in the functions of the limb over those retained after the secondary. The consensus of opinion amongst surgeons is now strongly in favour of primary excisions of the elbow. MacCormac did four primary excisions, during the Franco-German War, with one death, and seven secondary with five deaths. But not much is to be gained by comparisons between the two procedures. Primary excisions are required in all extensive comminutions of the elbow in which the destruction of the soft parts and of the bones is not so extreme as to necessitate immediate amputation; secondary excisions must be performed on the failure of conservative treatment, when the patient has survived the dangers of suppuration in the joint, and it has become evident that consolidation of the fracture cannot occur. Upon one point all are agreed, that the operation should be avoided in the intermediate period.

The Operation should be performed through a posterior longitudinal incision over the olecranon process, outside of the ulnar nerve, and as far as possible the sub-periosteal method should be used. The joint should be thoroughly

irrigated with a weak corrosive sublimate or carbolic acid solution, drainage maintained for twenty-four or forty-eight hours, and the usual gauze and wool dressings put on. MacCormac considers that a splint is seldom required in these cases, unless transport of the patient is a necessity; the limb may be comfortably placed on pillows, and, as mobility of the joint is to be desired, a fixed apparatus

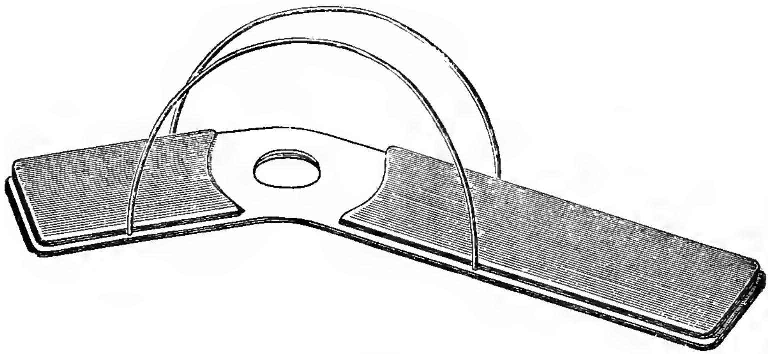


FIG. 43.

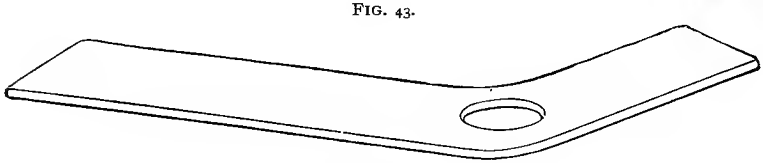
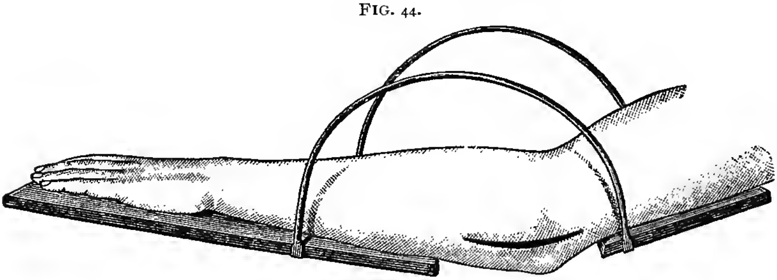


FIG. 44.



FIGS. 43, 44, and 45.—Esmarch's Splint for Resection of Elbow.

is not required. If a splint be used, Esmarch's double splint, suspended at the level of the patient's shoulder (figs. 43, 44, and 45), is probably the best and most convenient, but any apparatus which will keep the limb at rest in a position of slight flexion will suffice.

Secondary Excision of the elbow, as already stated, is indicated in cases of persistent chronic arthritis and suppuration of the joint, accompanied by exfoliation of fragments of necrosed bone, when nothing further can be expected from conservative measures which have failed to save the joint. The treatment of the secondary cases is similar to that suggested for the primary, except that very accurate disinfection of the joint by means of the more powerful antiseptic lotions must be attended to, and that free drainage will be required for some considerable time.

Amputation in cases of gunshot wounds of the elbow is required in all very extensive fractures of the joint where the crushing and destruction of the bones and of the soft parts are so great as to put excision out of the question, and when destruction of both the main nerve trunks accompanies fracture of the joint. Injury to the main artery is not so certain an indication for amputation in elbow cases as it is in gunshots of the shoulder, some few instances of this kind having recovered under less radical means; but it is a complication which requires to be well considered, and which greatly interferes with recovery of the uses of the forearm and hand, even if gangrene does not result.

Secondary Amputation may be necessitated by extensive necrosis, osteomyelitis, secondary hæmorrhage, and for the removal of a limb which only proves to be a useless encumbrance.

The Statistics of gunshots of the elbow joint treated by the different methods, have varied considerably in different wars. The following table gives the results observed in the American War:[1]—

Mode of Treatment.	Cases.	Mortality.
Conservation	938	10.3 per cent.
Primary excision . .	322	21.3 "
Intermediary " .	197	35.2 "
Secondary "	54	9.2 "
Period unknown . .	53	8.3 "
Amputations above the joint	5456	23.6 "
Amputation at the joint .	6	16.6 "

[1] Otis.

Amputation through the lower third of the humerus for gunshots is a more fatal operation at all periods, whether primary, intermediate, or secondary, than are amputations in the middle or upper thirds. A careful study of the records of over 5000 cases seen in America affords to Dr. Otis no sufficient explanation of this fact. Delorme considers that it is due to the operation being so frequently performed in the lower third for fracture of the elbow, and that in these cases the section of the bone is made below the true limits of the lesion, and therefore through fissures in the lower end of the humerus. Moreover, he believes that modern methods of treatment will, in the future, lessen the mortality following amputation in the lower third of the humerus, and make it conform to the general rule in surgery, that the farther the site of an amputation is placed from the trunk, the less will be the death-rate following it. Delorme's suggestion is probably correct, as it is borne out by a similar observation made regarding gunshots of the lower limb, that amputations in the lower third of the femur for wound of the knee are more fatal than those done for fracture of the lower third itself.

Gunshots of the Wrist and Carpal Joints.

Gunshot wounds of the wrist and carpus are not a very fatal class of injury; in the American War, under all methods of treatment, they gave a death-rate of 12.9 per cent., and in the Franco-German War the mortality was still less. On the other hand, recovery with anything like normal or even useful motion in the hand and finger joints has hitherto been quite exceptional.

A bullet passing through the carpus in an antero-posterior direction, or *vice versâ*, causes much less damage to the bones than does one traversing it from side to side. The modern bullet of small diameter is less likely to divide tendons than were the larger leaden projectiles of former days, and the injury produced by the former on the cancellous structure of the carpus is almost confined to pulver-

ising the bones it actually comes in contact with, the others remaining unaffected.

Conservative Treatment is indicated in the large majority of these cases. The mortality resulting from this method in the American War was 7.6 per cent., but this ratio only represents the death-rate in cases in which secondary operations were not performed. This is greater than the mortality of gunshots of the forearm, but much less than that of amputation in the forearm for wrist injury. In the Franco-German War conservation gave a death-rate of 11.4 per cent.[1]

The results of conservative treatment, as regards the preservation of the functions of the hand and fingers, have been extremely bad, and those of excision cannot be said to have been any better. Both methods of treatment usually end in ankylosis, more or less complete, of the wrist and of the finger joints, frequently accompanied by considerable deformity of the limb. This is due to obliteration of the synovial sacs, and matting together of the numerous tendons and their sheaths which are in such close relationship with the wrist joint. Of 382 cases treated conservatively in the war of 1870–71, ankylosis occurred in 226. In the American War, out "of 68 men whose hands were preserved, 51 had ankylosis at the wrist, 5 mobility with deformity, and 3 flail joint."[2] Conservative treatment should be practised in all cases where the degree of injury does not indicate immediate amputation in the forearm, because the results of excision, as regards both the preservation of life and the recovery of the use of the limb, are better when it is performed as a secondary operation.

The wound of exit in these cases is always larger than that of entrance, and it is usually of sufficient extent to permit of irrigation of the wound and of the synovial sacs, which should always be thoroughly done with a weak antiseptic solution. Loose fragments and pulverised carpal bones should be removed, drainage provided for, and the usual dressings applied. A splint, extending from the finger tips to above the elbow (which should be slightly

[1] Delorme. [2] Otis.

flexed), should be applied to the anterior surface of the limb, and slung as in cases of excision of the elbow.

Should suppuration within the joint supervene in the course of the treatment, incision on one or other lateral aspect of the back of the wrist, parallel to the extensor tendons, should be made as early as possible, to give exit to pus, and for the relief of tension, which is especially injurious in connection with this joint. The tendinous and ligamentous structures about the wrist are so strong, that, unless this be attended to early, pus will travel up the forearm in the direction of least resistance, and many incisions will be required for the evacuation of the abscesses which will result. All loose fragments of bone must also be removed. If this be not considered sufficient, a partial or complete secondary excision must be performed. The joint should, in either case, be well irrigated and disinfected with 1–1000 corrosive sublimate or 1–40 carbolic acid solution, and freely drained.

Excision of the Wrist.—The results obtained during the American War by excision of the wrist were not at all favourable as regards the preservation of the functions of the hand. Partial operations were done as a rule, and most of them were performed during the primary period. During both the American and Franco-German Wars excision gave a mortality equal to twice that of conservative treatment; and as regards "end-results," Gurlt returns 6.25 per cent. of those done in the war of '70–71 as "good," and 93.75 per cent. as "moderate," "bad," and "very bad." Some of the ill success in the excisions done in America for gunshots of the wrist was, no doubt, due to faultiness in the operative procedure, L- and H-shaped incisions and Velpeau's quadrilateral flap being employed, all of which interfere with the tendons and their sheaths unnecessarily. But the principal cause of bad results after this operation was the absence of asepsis in the wound. Suppuration in such a joint as the wrist must be followed by complete, or almost complete, loss of movement in the parts below it. The obliteration of the intricate system of synovial sacs in the carpus and wrist joints, and the firm adhesions which

the network of cord-like tendons passing on all sides of them must form to each other and to the parts around, cannot result otherwise than in ankylosis. The results obtained by the American surgeons were the only ones attainable in those times. Asepsis in wounds was not known during the American War, and Lister himself was only then beginning to suggest its possibilities. The work of the surgeons during that war was probably the greatest of its kind ever done, and it is worthily recorded in the "Surgical History of the War of the Rebellion," by Dr. Otis. But with aseptic methods of dressing and treating wounds, we may look for different "end-results" in wrist cases, as in all other gunshots of joints.

Primary Excision should be performed in all severe comminutions of the articular ends of the radius and ulna due to gunshots; in cases of similar severe injury of the carpal bones alone; and in cases where both the carpus and the bones of the forearm are fractured.

The operation should be a partial one when the carpus alone, or only some of the bones forming the wrist joint, are injured, the fractured portions only being excised. When a partial excision is done for fracture of the lower end of the radius, the lower end of the ulna should be removed to the same extent; otherwise deformity in extreme abduction, the hand being pressed towards the radial side by the projecting ulna, is certain to occur. Delorme, on the whole, recommends conservative treatment, even in severe cases, and when the probability of having to do a secondary excision is great; but how far complete asepsis in the wound will have the effect of overcoming the objections to excisions during both periods has yet to be experienced. In the Russo-Turkish War of 1876, excision of the wrist was performed eight times with no death; and, as already stated, it was in this campaign that the first serious attempt was made to use antiseptics in war.

Secondary Excision will be required for gunshots of the wrist when suppuration supervenes in joints which are being treated conservatively, and for injuries which are found to be of a more extensive character than was at first

suspected. Complete excision of the joint will probably give better results at this period than the partial operation.

The Operation should always be done according to Lister's method; for it has only been since this came into common use that anything like satisfactory after-results have been obtained even in cases of disease, and Lister's splint for excision of the wrist is the best apparatus to use in the after-treatment (figs. 46 and 47). By its employment the two great objects to be desired, firm union at the wrist, and normal mobility of the thumb and finger joints, are most likely to be best attained; for, while the forearm

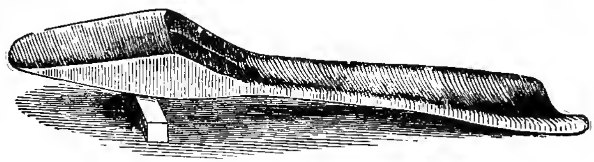
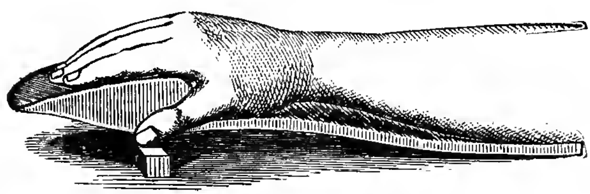


FIG. 46.



FIGS. 46 and 47.—Lister's Splint for Excision of Wrist.

and wrist are maintained immovable, passive movements of the thumb and fingers can be readily carried out. Passive motion of the latter should be commenced within a day or two of the operation, and persevered in while any tendency to contraction remains. The more time and care expended in preserving the movements of these joints the better will be the "end-results" obtained in wrist cases. A special matter to be attended to is the liability of the thumb to become contracted towards the index finger, and the space between the thumb and finger should be filled with wool padding to prevent this taking place.

Primary Amputation in the forearm for gunshot wounds

of the wrist may be required when these injuries are accompanied by extensive fractures of the bones and lacerations of the soft parts of the hand. In the American War these operations were somewhat more fatal than similar procedures for gunshots of the forearm itself—15.5 per cent. as compared to 13.9 per cent. Amputations at the wrist joint gave a mortality of 10.6 per cent.

CHAPTER VII

GUNSHOT WOUNDS OF THE HIP JOINT

GUNSHOT wounds of the neck of the femur and of the hip joint are without doubt the most dangerous of all joint injuries. They are, indeed, probably the most fatal class of wound ordinarily seen in war hospitals. During the American War 386 cases were recorded, and, under all methods of treatment, gave a death-rate of 84 per cent.; while no other class of gunshot wounds, including those of the cranium, the sufferers from which survived long enough to arrive at a hospital for treatment, afforded as high a ratio of deaths.

The diagnosis and treatment of gunshot wounds of the hip are surrounded with difficulties. Probably every surgeon who has written on the subject has alluded to the large number of cases which are met with in which certainty, or even an approximation to certainty, in diagnosis of actual joint implications is impossible. Hennen[1] wrote: "In some of these cases the course of the ball is so obscure, and its place of lodgment so uncertain, that it can only be detected after death." That the difficulties of diagnosis are sometimes insuperable, has been corroborated by Hamilton as the result of the experiences obtained in the American War, and by Billroth and Deininger regarding those of the war of 1870–71. Billroth states: "I am of opinion that the direct injury of the joint capsule and bone cannot (always) be early diagnosed"; and Deininger, that "the difficulty of diagnosing a hip-joint fracture (gunshot) in its early stages is very great; frequently it can only be ascertained in the course of the case whether the joint is really injured, and sometimes the fracture is not discovered until after death."

[1] "Principles of Military Surgery," 1820.

The obstacles to the accurate diagnosis of cases of gunshot wound in the immediate vicinity of the hip are to be found in the anatomical situation of the joint, and in the occasional absence of those physical signs which surgeons expect to observe when the neck of the femur is fractured. The joint is so deeply placed as to be almost inaccessible to examination with the finger, and exploration with instruments is a substitute of but little value. The bullet track passes through thick masses of muscle and strong fibrous structures, the apertures in which may not coincide at the time of examination, and it may be impossible to make out even its general direction except for the first part of its course. Then, again, the physical signs of fracture of the femur in the immediate neighbourhood of the hip may be absent: there may be neither shortening of the limb, eversion of the foot, obvious displacement of the bony points about the joint, or escape of synovia. Even more than this, the patient may be able to move the limb, and actually to walk, although the hip joint may have sustained a severely comminuted fracture. Many cases are on record where there was at first hardly any disturbance of the functions of the joint, although serious and even fatal injury had been inflicted. Legouest[1] details a case of complete fracture of the rim of the acetabulum, where the man continued to walk for many days. Fischer describes two similar cases where the ball lodged in and shattered the head of the femur, and yet the men could walk.

Small-bore bullets are even more likely to produce fractures of this kind than were the old leaden bullets. The former are more likely than the latter to traverse the spongy ends of long bones without producing displacement of the fragments, and in these cases it is more probable that these may be so held together by their periosteum and by the ligamentous tissues in connection with them, that the functions of the limb may be for a time but little interfered with, and the patient able to walk for some little distance. This condition, it need hardly be pointed out,

[1] *Chirurgie d'Armée*, 1872.

may tend to lead the surgeon to exclude injury to the hip joint from his diagnosis.

Difficulties of diagnosis in these cases are, then, certain to be met with; and there are two methods of treating these doubtful injuries. In the first place, the surgeon may decide to treat a case in which the situations of the wounds of entrance and exit lead him strongly to suspect injury to the joint or its capsule, as certainly a joint injury, although the signs usually accompanying this condition are absent—to treat it, in fact, conservatively, or, rather, "expectantly"; or, in the second, he may enlarge one of the wounds, and persevere in his efforts at diagnosis until he clearly understands the class of case he has to deal with.

It by no means follows, although it is probable, that the cases in which these difficulties arise are always the most simple. The comminution of the head and neck of the bone may be extensive; but, if the fragments are well held together, the symptoms of fracture may not at first develop, nor the functions of the joint be lost. When we remember that hitherto all gunshots of the hip have been followed by an enormous death-rate, that some even of the cases above referred to may be so severe as to require a primary excision, that correctness of diagnosis is a necessity to correct treatment, and that the fate of the patient depends on his injury receiving, as early as possible, the treatment suitable for the particular case, the indications as to which of the two procedures the surgeon should adopt in doubtful cases will be fairly apparent.

Enlarging one of the wounds, an exploration of the joint, can add no extra danger to the case. If the joint be found intact, then the bullet wound and its enlargement are comparatively trivial matters; whereas, if it be discovered that it has been implicated in the passage of the bullet, the surgeon will feel confident that he has at his disposal the necessary data on which to base his treatment of the case, and he will only have done that about which he would have had no hesitation had he known the true condition from the first. But to warrant this operation

two conditions are required—(1) that, judging from the positions of the wounds, and the direction of the track of the bullet between them, there is a high degree of probability that the joint must be implicated; and (2) that the surgeon is so well supplied with antiseptics that, with proper care, contamination of the wound is an impossibility.

Langenbeck refers to one sign of joint injury in doubtful cases, to which he attributes much value—the swelling of the articular capsule with blood, which is most apparent in the front of the thigh below Poupart's ligament, where it is most superficial. As the result of this distension, the large vessels of the groin are pushed forwards, so that the femoral artery is seen to beat close under the skin in the groin.

Careful observation of the entrance and exit wounds made by modern projectiles should enable a surgeon who knows the anatomical limits of the joint to judge as to the probabilities of its being injured. As already mentioned, the track of a small-bore bullet may be taken to be the line between its entrance and exit. Hardened bullets of small diameter, travelling at high rates of velocity, are not often deflected from the straight line of their flight by animal tissues; and therefore when the track of one of these missiles appears to traverse the hip joint, it may be taken that the joint is implicated, although other signs of this accident may be wanting.

Langenbeck defines the "dangerous region" in hip cases as "a triangle whose base intersects the trochanter major, while the femur and the anterior superior spine of the ilium form the points of an acute angle."[1] The utility of any mathematical figure bounding "the dangerous region," for the purpose of helping the surgeon in his diagnosis of doubtful cases, is very uncertain; but, even if one be required, Langenbeck's triangle is faulty, in that it includes within its area a considerable space which is outside the joint. A better one would be a triangle the angles of which are at the spine of the pubes, the anterior inferior

[1] "Surgical Observations on Gunshot Wounds of the Hip Joint," translated by J. F. West, F.R.C.S., Birmingham, 1876.

spine of the ilium, and the outermost point of the great trochanter. The fault of this definition of the dangerous region is that it also extends too far on the inner side. The joint will be most directly involved when the bullet penetrates close below the anterior inferior spinous process, and in the direction of the median line; the head of the femur will be injured in such a case. If the entrance of the bullet be close below, and external to the spine of the pubes, and the exit be in the region behind the trochanter major of the same side, the hip joint will, as a rule, be injured, with probable separation of the edge of the acetabulum. When the entrance and exit wounds are in front of and behind the trochanter major, injury to the neck of the femur and opening of the capsule of the joint may be assumed as certain.[1] Fractures of the great trochanter are usually limited to that process alone, without very extensive fissuring; but occasionally fissures extend into the shaft of the femur for some distance, and through the neck into the joint itself.

Treatment of Gunshot Wounds of the Hip.—The treatment of this very serious and fatal class of injuries may be considered under four heads—(1) Expectancy; (2) Conservation; (3) Excision; and (4) Amputation.

Expectant Treatment, although practised by some surgeons in cases of doubtful injury to the joint, where other signs are wanting, and there is nothing but the apparent direction of the bullet track to lead to suspicion of its implication, is only warranted when the doubt is so strong and the suspicion so weak as not to justify any exploratory or operative procedures. It is carried out by thorough asepticisation of the wounds and of the skin, the application of dry gauze and wool dressings, and the use of immobilisation and extension apparatus, the means for which will be referred to later on. This is, in the strictest sense of the term, expectant treatment. It is the policy of absolute non-interference and awaiting events. In cases of slight injury to the joint, in consequence of wound of the capsule only, or even in cases of very simple injury to the

[1] Langenbeck, *op. cit.*

bone, excluding those in which lodgment of the bullet occurs, this method is likely to be followed by the most happy results. But the recognition of the cases suitable for this mode of treatment, those in which the damage to the joint is only of the simplest degree, will always be the difficulty. If the guess at diagnosis—for it can hardly be more than that—prove correct, all will be well; if incorrect, then valuable time will have been lost, and the true condition will only become apparent when it is already too late to permit of primary resection, an operation which might have saved the patient's life, whereas he will now have to run the risks of the inflammatory period—not, indeed, necessarily fatal,—but productive of very high death-rates. The impossibility of guaranteeing absence of severe bone lesions, from the want of the usual signs of fractures of the head and neck of the femur, has already been alluded to.

Conservative Treatment.—Previous to the publication of the third volume of the "Surgical History of the War of the Rebellion," by Otis, and of Langenbeck's "Memoir on the Treatment of Gunshots of the Hip Joint," after the Franco-German War, very little expectation of the recovery of these cases, when treated conservatively, existed in the minds of army surgeons. The older men, those of Guthrie's time, stated fairly that this result was impossible. Otis gives a table showing that 304 cases were reported as having been so treated during the American War, with 55 recoveries, or a mortality of 81.5 per cent.; but on further inquiry, and careful study of the histories of these cases, he eliminates 52 of them on the ground that "the evidence is contradictory, or averse to the supposition that the hip was implicated," thus leaving only 252 authenticated cases of gunshots of the hip treated conservatively, with three recoveries, or a mortality of 98.8 per cent. "Of the three cases of undoubted intracapsular gunshot fracture of the hip joint which recovered, one died four years later, pus and splinters of bone having been constantly discharged during the interval; in the second case so much bone had been removed by operation that it

was a disputed point whether it should be regarded as an example of excision or as one of conservation; the third patient was in tolerably good health in 1878."

Naturally, under these circumstances, the opinion held by Dr. Otis of the conservative treatment of gunshots of the hip was not a very favourable one. He summed up his conclusions by saying: "Of temporisation in the treatment of hip cases, I must continue to share the unfavourable impression of Guthrie, and many of the older as well as more modern writers on military surgery, and can only reiterate the conclusion that I have already expressed in circulars No. 6 and No. 2, that shot injuries of the hip joint, when abandoned to the resources of nature, prove almost uniformly fatal."

With the results he had before him no other opinion could have been held. But it may be that these results are to be accounted for by the methods of treatment which we may infer from the use of the phrases "temporisation" and "abandoned to the resources of nature." Modern scientific conservative surgery admits of the employment of no such terms in reference to it. Patients subjected to it are by no means abandoned to the resources of nature, and the surgeon who employs it does not merely temporise. All the resources, not of nature, which is incapable of the cure of such injuries, but of the best developments of modern surgical procedures, are brought to the aid of the patient: the surgeon does not merely await events, but endeavours to put the injured limb, from the first, in the best possible condition for recovery.

Langenbeck, on the other hand, speaks with no uncertain voice in favour of the opposite view of this question. "I have undertaken to prove," he says, "that gunshot wounds of the hip joint, and even most severe cases, may be cured by conservative treatment; that in the last war (1870–71) not a few well-established successes have been effected." He has shown that the experiences of the Franco-German War proved that the proportion of recoveries under a conservative line of treatment was greater than when primary resection or amputation was resorted

to. All the cases of amputation in that war proved fatal, and out of 31 cases of resection only 4 recovered, a mortality of 83.8 per cent.; while amongst 88 cases treated conservatively, there were 25 recoveries, or a mortality of only 71.5 per cent. And besides Langenbeck, Demme, Pirogoff, Gross, Spillmann, and many others have taught that the value of the conservative plan of treatment of gunshots of the hip has been inadequately appreciated by army surgeons, and have collected cases tending more or less to prove that such injuries, when so treated, are not uniformly fatal.

Of the Means to be employed in the conservative treatment of wounds of the hip joint, accurate diagnosis at the earliest possible moment is of the very highest importance. A clear knowledge of the condition of the joint is necessary in order to exclude from this method cases of the more severe kind which require the operation of primary excision.

In cases where the usual signs of fracture about the head and neck of the bone are absent, the direction of the bullet track must be carefully considered, so that the surgeon may be able to estimate the probabilities for and against wound of the joint capsule.

Capsular wounds, incomplete fractures of the neck of the femur, and fractures of the rim of the acetabulum, are the cases in which the difficulties of diagnosis are greatest, in consequence of the absence of the physical signs already referred to. If there be no doubt as to the existence of wound of the joint, and fracture of the bones composing it, the wound should be enlarged sufficiently to admit of complete exploration by means of the finger, and a definite opinion being formed as to the degree of comminution of the bone, and as to the suitability of the particular case for one or other of the different modes of treatment. Langenbeck is uncertain as to the advantages of unconditional dilatations of all fresh wound apertures merely for the purposes of diagnosis, and he considers it as entirely unadvisable in cases of joint wounds which one has decided to treat conservatively. No doubt this is correct teaching

as far as it goes. If the surgeon has made up his mind to treat a case conservatively, the wound should not be enlarged for the purpose of further diagnosis: accurate knowledge of the condition of the joint is only required for the purpose of determining the treatment; therefore when the latter has already been finally fixed upon, diagnosis may be set aside.

But the large majority of cases, treated by this method, which have proved fatal, were shown, on further observation or on dissection after death, to have been of a nature which from the first rendered them unsuited for conservative treatment. They were cases which, had the wounds been enlarged and explored, would have been treated by primary excision, or even by more radical means. The records of the fatal cases treated conservatively enumerated by Otis, by other army surgeons, and even some of those by Langenbeck himself, all contain notes such as—"this case was not at first suspected to be one of actual joint injury;" "supposed to be a mere capsular wound;" "joint injury not known;" "fracture not suspected," &c.; the inference being that, had the true condition been recognised at an early date, conservation would not have been attempted. The only means by which this essential knowledge can be attained is by enlarging the wounds and exploring with the finger; and on these grounds I submit that these procedures should be carried out in all cases of gunshots in the region of the hip joint when injury to the neck of the femur or to the bones of the articulation *is suspected*. With proper precautions not to contaminate the wound with septic matters, they can include no additional risk to the patient's life or limb; the suitability, or otherwise, of the case for conservative measures will be determined; loose splinters can be removed; irrigation can be practised; and effective drainage can be maintained.

Langenbeck directs attention to the necessity of the removal of bullets lodged in the joint or its vicinity. This may be done through an enlargement of the wound, or by means of a fresh incision, as may be most convenient.

All authorities are, however, agreed that, in cases of

undoubted bone injury, enlargement of the wound and exploration are necessary, for under such a condition it becomes a question of operation, and the examination must be made to decide whether it shall be primary excision or amputation at the joint.

The Cases which are suitable for conservative treatment, according to Langenbeck, are those in which only the capsule of the joint is wounded, or is suspected of being wounded; and those in which the injury to the bones of the joint is so slight as not to interrupt the continuity of the neck of the femur. Langenbeck lays it down that this method "should not be adopted either for intra- or extracapsular fractures of the neck of the femur if the continuity of the bone is quite destroyed." "As recovery from these wounds hardly ever occurs without suppuration in the joint, consolidation of the fracture must be looked upon as impossible, and necrosis of the head, at all events in intracapsular gunshot fractures, as unavoidable. The opportune performance of resection or extraction of the head of the femur must be taken into consideration in these cases."

This is far too close a restriction of the possibilities of conservation for the more scientific surgery of these days. As Langenbeck states the case, no doubt he is correct. If it were true that "suppuration nearly always occurs in the joint," it certainly would be true that "consolidation of the fracture must be looked upon as impossible." Perhaps suppuration did take place in most of these cases in the war of 1870–71, but now there is no more reason why it should occur in them than in the compound fractures treated in civil life, and, without it, much more severe injuries than those indicated by Langenbeck as suitable for conservative treatment should recover by means of it. Capsular injuries; fractures of the head of the femur; fractures of the neck of the bone, which are simple as regards the degree of comminution; fractures of the great trochanter, which often do not greatly implicate the joint—all these are amenable to successful conservative treatment if only asepsis can be maintained.

The procedures to be carried out in the conservative treatment of gunshots of the hip are—(1) the exploration of the joint where bone injury is suspected; (2) the removal of splinters; and (3) the immobilisation and extension of the limb.

Exploration, if there are two wounds, can usually be more readily done through the wound of exit, and in performing it the minutest precautions against contamination should be observed. The skin aperture should be enlarged only just sufficiently to enable the finger to reach the joint and ascertain the degree of fracture, and the presence or otherwise of loose splinters which require removal.

The removal of splinters of the fractured head or neck of the femur is a difficult and tedious procedure—far more so, indeed, than is a systematic resection of a diseased hip joint. They are usually found bound down by the capsule and ligamentous structures, the apertures in which are not large enough to allow of their extraction, and if the fragments are large and numerous the operation resolves itself into a true arthrectomy of the hip. The cases which include the removal of numerous and large fragments of bone are hardly suitable for purely conservative treatment; under these circumstances the scope of the operation should be increased, and a primary excision completed. Only those splinters which are quite free from adherence to the main portion of the bone, and to the periosteum and other soft parts, should be extracted. After the removal of the bone splinters the joint should be irrigated, and its drainage provided for; and for this purpose, if the wound be not already in a dependent position, the tube should be passed from the joint, through a button-hole in the skin behind the great trochanter.

The importance of immobilisation of the limb, combined with extension and counter-extension, is hardly second to that of asepsis in the wound. As the best means for this purpose, Langenbeck recommends the plaster of Paris apparatus; but, as he himself admits, this is too troublesome, and requires too much time and too many skilled assistants in its application, to be of use in field

hospitals. He also states that in these cases the fixed apparatus should be put on where the man falls on the battlefield. If this were a necessity of successful treatment, it would preclude all attempts at conservation. But, on the other hand, Delorme considers that bandaging the injured limb to the sound one, while the inequalities between the knees and ankles are well padded with cotton-wool, affords sufficient fixation during transport to the field hospital.

Whatever means be employed for immobilisation, it must include the pelvis and the whole limb, and it should be applied as soon as possible, that is at the dressing station or at the first field hospital. If this is not done, if the men with injuries of this class have to be passed far to the rear, the opportunity for conservative treatment with good prospect of success will almost certainly have been lost.

The immobilisation of the limb and joint in these cases will always be the great difficulty in their treatment, even when the patients need not be transported. Wire-gauze splinting, or the sheet-zinc splints suggested by the Austrian surgeon Schön, are very suitable. Both of these, although very flexible when flat, become quite rigid when bent into the hollow shape required to half-surround the leg and thigh, and afford ample support. Splints of this kind might be applied at first, and, later in the treatment of the case, plaster of Paris apparatus, the only objection to the use of which from the beginning is the time it takes to apply it, might be substituted.

Whatever fixation apparatus be used, the wounds must, of course, be left as far as possible uncovered by it so that the dressings may be attended to without its removal. It is almost impossible to have prepared fixation apparatus for these injuries ready for immediate use in war hospitals, and the ingenuity of the surgeon who wishes to try conservative treatment in such cases will be severely tested in making the best possible arrangements for immobilisation with the means at hand, under very trying circumstances.

Permanent Extension by means of weights is an equally

important matter both for wounds of the hip and for gunshot fractures of the shaft of the femur. Langenbeck calls it "a true panacea"; and fortunately, even in warfare, it is easily applied if the patient has not to be moved. If beds are available, the method of extension is simplicity itself, as every surgeon knows: with the foot of the bed well raised off the ground, a stirrup of diachylon plaster reaching well up the leg affords a point of traction for a cord and weight. If beds cannot be obtained, a piece of stick, with a hole in the end for the cord and weight, is fastened in the ground a short distance from the patient's feet, and extension made in the same way, except that, in this case, means of counter-extension must also be provided. Sandbags should be placed on either side of the limb, and care must be constantly exercised to prevent the eversion of the foot, to which there is a tendency during the whole course of these cases.

The value of extension can hardly be over-stated. By means of it the joint is kept at rest and in the best position, the straining and jerking of the powerful muscles are overcome, and the pain is relieved by the removal of the inter-articular pressure which tends to produce inflammatory cartilage and bone mischief. Even when the wound has healed, extension must still be continued to overcome the tendency to flexion at the hip, to obviate contraction, and to ensure ankylosis in good position.

If suppuration occur within the joint, and infiltration into the soft parts about it, an incision should be made behind the great trochanter. Through it, splinters which may have become loose during the treatment should be removed, and irrigation diligently practised with the stronger antiseptic solutions. Conservative treatment may be considered to have failed when suppuration supervenes, but nevertheless excision is not indicated at this period. Excisions of the hip done during the inflammatory period are far more fatal operations than those performed during the secondary. We should therefore endeavour to tide the patient over the time of active inflammation and suppuration by means of suitable nourishment and stimulants while

paying attention to the treatment of other collections of pus, and to the free drainage of the wound and of any abscesses which have required opening. If these methods prove successful, if fever abates and the discharge lessens, the secondary excision may then be performed with a fair prospect of saving life.

Hitherto ankylosis has been the common result in gunshots of the hip which have recovered under conservative treatment. Langenbeck's experience does not allow him "to decide whether it be possible for even a simple capsule wound to heal with preservation of the power of movement." He does not deny the possibility, but he has never seen it. Where suppuration occurs, ankylosis may be expected with certainty; but if this be avoided, these simple injuries, as well as others of greater severity implicating the bone, should recover with some, or even good, movement in the joint. This occurs in the knee, a much larger and more complicated articulation, and it should occur in the hip; though possibly not so frequently, in consequence of the ball-and-socket arrangement of the latter joint as compared with the hinge formation of the former. Even if ankylosis does take place, this must be considered a very satisfactory result to obtain after so terribly fatal an injury as a gunshot of the hip.

Langenbeck is very doubtful of the advantages of true Listerism in the field, although admitting its good effects in civil practice. But we must remember that he writes of the very early days of these methods as used in warfare, and, moreover, that other surgeons, Carl Reyher, for instance, in the Russo-Turkish War, obtained, by the antiseptic treatment of gunshot wounds of joints, results until then unheard of, which are detailed in Mr. Watson Cheyne's "Antiseptic Surgery," and have already been referred to in a previous chapter. Conservative treatment of gunshot fractures of joints and of long bones has already produced fairly good results, considering the adverse circumstances under which it has been carried out; but, in the future, surgeons may with certainty look to a vast improvement in the mortality rates and in the number of limbs saved

after the receipt of these injuries, even in war, when treated on modern principles.

Excision of the Hip.—The records of this operation as performed in military practice in the field have not, up to the present time, afforded much encouragement to army surgeons. The mortality following it, irrespective of the period at which it was undertaken, has been extremely high. Otis has collected statistics of 161 cases of excision of the hip for gunshots in which the final results had been ascertained: the primary operation yielded a mortality of 93 per cent.; the intermediate, 96.6 per cent.; and the secondary, 63.4 per cent. The operation was performed 66 times during the War of the Rebellion, and furnished a somewhat higher death-rate. Gurlt's statistics of the last four German wars place the death-rate for the operations done at all periods at 90.5 per cent.: during the primary period, 1 was done, and proved fatal; during the intermediate, 7, with 85.7 per cent. mortality; secondary, 43 cases, with 90.6 per cent. mortality; later, 2 cases, both of which were fatal—in all, 53 cases, of which 48 died, or a death-rate of 90.5 per cent. Langenbeck s table for the Franco-German War gives 31 cases, with 26 deaths, or a death-rate of 83.8 per cent. Prior to the American War the operation had been done for gunshot 16 times, with only 1 recovery, viz. the case performed by Surgeon O'Leary, of the 68th Regiment, in the Crimea.

The conclusions arrived at by Otis, judging from his exhaustive research into the records of all known cases, were that in the primary period the operation is extremely grave, that in the intermediate period it is nearly always fatal, and that in the secondary period it offers the patient some chance of life. In criticising the records and notes of the cases of this operation in the American War, and suggesting reasons for its extreme mortality, he points out that "at least nine of them were complicated with such lesions of the pelvic walls and viscera as made any operative interference useless"; that it was performed in unsuitable cases, those in which there were extensive fractures of the upper portion of the shaft of the femur as well as of

the joint; and that many of the patients had to be subjected to long transport during their treatment. But even with all this, he considers that "the fact that of 171 patients on whom excision at the hip for shot injury is known to have been performed to the present date, 23 survived, it must be admitted that the results of this operation, so far, have been encouraging in an almost hopeless class of cases."

There is a good deal of evidence to show that conservative treatment was not sufficiently appreciated during the American War, and indeed in other campaigns, the inference being that excision must have been too lightly undertaken. Otis says that "primary excisions of the head or upper end of the femur should be performed in *all uncomplicated cases of shot fracture of the head or neck*"; that expectant treatment is to be condemned in all cases of direct injury to the articulation. Löffler remarks that "the conservative treatment of this injury, according to the experience hitherto acquired, gives no prospect of saving life."

To treat gunshots of the hip on the lines to be inferred from these statements implies far too wide an application of excision. It is by no means true that conservation affords no prospect of saving life, nor is it the case that uncomplicated fractures of the head or neck of the femur require primary excisions. These are, in fact, the very cases which are most suitable for conservative treatment, and in which excision is directly contra-indicated. Surgeons who enunciate views such as the above, no doubt, treated their cases in accordance with them, and naturally have but indifferent results to record of both methods of treatment.

Primary Excision.—Delorme is of opinion that the great improvements which have been made within recent years in the treatment and dressings of wounds can hardly be expected to reduce the mortality of primary resections of the hip in any marked degree. He points out that the very large majority of fatal cases operated on up to the present date died within the first few hours, under twenty-four hours at the outside, in consequence of the combined

shock of the injury and of the operation. While this is true to a large extent, it does not apply to the cases in the American series, a considerable number of which are stated to have succumbed to pyæmia or other infective disease, and it may very well be that many of these would not have proved fatal had an aseptic condition been preserved. Antiseptics will be no less effective in saving life in those cases of primary resection which do not die of shock within the first twenty-four or forty-eight hours, than it will be in obviating the necessity of performing intermediate and secondary resections in cases treated at first conservatively.

FIG. 48.

Gunshot of Neck of Femur.—*Netley Museum.*

The Cases requiring the Operation of Primary Excision of the hip joint are those which, on exploration through the wound, are found to be complicated with splintering of the head or neck, or of both, to such a degree as to render cure improbable under conservative treatment; cases in which not only the continuity of the neck of the femur is lost, but also so much bone matter in the form of splinters and small fragments have to be removed as to constitute a practical excision of the joint (fig. 48). In fact, systematic excisions are seldom indicated as primary operations. The operative procedure which is substituted for these is one for the removal of loose splinters, to which is added the removal of the jagged portions of the neck of the femur by means of the saw. Delorme rightly insists that we should be care-

ful not to remove considerable portions of the head which are still joined to the neck of the bone, merely for the satisfaction of doing a systematic operation. If the head be fractured throughout, and retains no connection with the neck, it should be removed, and the neck trimmed with the saw.

Intermediary Excisions may be required in cases which were suitable for the primary operation, but in which it was not performed, either in consequence of want of accuracy of diagnosis, or because some insurmountable difficulty intervened to prevent it. It must be remembered that all operations—and this one more than most others—done in this period are followed by much higher death-rates than those performed at other times.

Secondary Excisions are required when suppuration and inflammation have supervened in cases treated by conservation, and in which, giving exit to the discharges, disinfection of the wounds, and drainage have failed to interrupt these processes; when necrosis of the head and neck has occurred; and when the removal of considerable portions of bone, in the form of secondary splinters which have loosened during treatment, is found to be necessary.

Two methods of performing excision of the hip are employed—one by the anterior incision, and the other by the posterior incision. The former was first suggested by Hüter, and has since been recommended by Mr. R. W. Parker, and used with excellent results by Mr. A. E. Barker. The anterior incision commences half an inch below the anterior spine, and passes downwards and slightly inwards for four inches, between the tensor vaginæ and glutæi externally and the sartorius and rectus internally. The posterior incision begins at about the same point, and passes downwards over the most prominent part of the great trochanter. Which of these should be selected depends altogether on the situation and extent of the bone injury. If the neck and head only are fractured, the anterior incision is very suitable; but if the bullet has struck the trochanter, or if splintering extends into it, and fragments of the process require removal, the posterior inci-

sion will be the more convenient. When the anterior position is chosen, it will be advisable to provide for drainage by passing a tube through a button-hole in the skin behind the great trochanter. In excisions for disease the section of the bone is usually made through the trochanter, so as to make certain of being clear of the tubercular tissues; but in excisions for gunshots the only indication for making the section through or below the trochanter major is the fragmentation of that process itself. If the damage to the joint and to the upper end of the femur is found to be so great that the bone must be divided below the lesser trochanter, Delorme considers that amputation should be immediately proceeded with; while Langenbeck recommends that the excision should be completed with a view to the removal of the limb later on, when the patient may be expected to be in more favourable circumstances, because its retention after the removal of so much of the diaphysis of the femur would be useless.

The exarticulation of the head of the femur from the acetabulum in these cases, complicated as they are by fracture of the head or neck, and where, therefore, the levering effect of the femur for this purpose is not obtainable, is a matter of some difficulty. It is best effected by freely incising the capsule, and grasping the head of the bone, or any portion of neck still remaining attached to it, in a powerful lion forceps, and twisting it outwards until it is held only by the round ligament.

The after-treatment of patients who have undergone excision of the hip is to be carried out on precisely the same lines as the treatment of cases in which conservation is being practised, and the means are the same. Continuous extension is required, but it should be by means of lighter weights than those used in conservative treatment, and the tendency to eversion of the limb should be counteracted by placing sand-bags on either side. The position should be one of slight abduction during the course of both methods of treatment.

The mortality of all the cases of hip excision performed in the wars in Europe since 1848, and in the War of the

Rebellion in America, is shown in the following table, according to Gurlt:—

Primary.		Intermediate.		Secondary.		Later.		Total.	
Cases.	Mortality.	Cases.	Mortality.	Cases.	Mortality.	Cases.	Mortality.	Cases.	Mortality.
44	90.69%	17	94.11%	71	87.32%	5	60.0%	137	88.23%

All the intermediary excisions done in the American War proved fatal.

Amputation or Disarticulation at the Hip.—Disarticulation at the hip is required in all very extensive injuries of the soft parts and bones about and forming the hip joint, and of the upper end of the thigh when too close to the joint to permit of amputation in the continuity. Such injuries are usually produced by large shell fragments, and are of such extreme severity as to place the cases outside the possibility of cure by conservation or excision. Wound of the hip complicated by wound of the large vessels requires disarticulation; but cases of this nature very seldom reach the field hospital for treatment, as in the very large majority of them the men die of hæmorrhage where they fall. Cases in which the thigh is torn off, or nearly so, close to the hip joint, also require disarticulation. Otis, Longmore, and some others have stated that gunshots of the hip joint, when complicated by a severe compound fracture of the limb lower down, or by wound of the knee, require disarticulation. But Delorme, naturally, remarks upon this that the results of conservation are more hopeful now than they were when Otis made this suggestion, and that, in his opinion, to necessitate disarticulation at the hip *one of the wounds* must be such as would indicate amputation.

Disarticulation at the hip is an extremely fatal operation. The following table, which excludes re-amputations, is taken from Otis:—

Amputations.	Total Cases.	Recoveries.	Deaths.	Ratio of Mortality.
Primary .	25	3	22	88.0%
Intermediary .	23	0	23	100.0%
Secondary .	9	2	7	77.7%

This gives a mortality for the operation at all periods of

91.2 per cent., while re-amputations through the hip joint only gave a mortality of 33.3 per cent.

Sir Thomas Longmore said,[1] writing of the primary operation, that "it should be confined to cases which are entirely hopeless without it, to injuries in which the damage done by the shot is not confined to the joint or upper parts of the femur in which resection could be employed, but is accompanied with laceration of the femoral vessels or other injuries to the extremity of so extensive and serious a nature as to leave no other surgical resource available. As a secondary operation for the results of inflammatory necrosis after gunshot injuries or after previous amputations in the shaft, the risk is less than it is in the cases where it is performed as a primary amputation." During the Crimean Campaign, in the English, French, Russian, and Sardinian armies, it was performed 44 times, and all the patients died. Delorme refers to the mention by Chenu of 34 cases since 1870, 11 of which were reported by Langenbeck and Deininger, all of which proved fatal. Nothing, therefore, has occured, since Longmore wrote the article of which the above is a quotation, to change the prognosis after this operation during the primary period.

Langenbeck had more expectation of success after primary disarticulation at the hip. He was strongly of opinion that those performed up to the time of his writing (the first German Surgical Congress, 1873) were all done too late, and he said: "I am still quite convinced that disarticulation of the thigh ought not to disappear from military surgery, and that if we do not regard all very severe gunshot fractures of the hip joint and of the thigh from the commencement as lost, so in all these cases primary disarticulation ought to be performed in the course of the first twelve or twenty-four hours. Further, he suggests that if, from one reason or another, this time has been allowed to pass by, resection should be performed with a view to amputation later on.

Surgeon-General B. Beck also considered this a hopeful

[1] "System of Surgery," T. Holmes.

procedure, and during the war of 1870 he had selected a case on which to try it. He had done the excision, and proposed to perform amputation fourteen days later, but was sent away before the time arrived. The only case on record where this plan was carried out for gunshot was one by Neudörfer in the Italian War of 1859, and the patient recovered.

Otis has collected statistics of 254 cases of this operation, with a death-rate of 88.9 per cent. Of these, 82 were primary, with a mortality of 91.4 per cent.; 55 intermediary, with 94.5 per cent. of deaths; and 40 secondary, with 82.5 per cent. of deaths.

From what is known of disarticulation at the hip, we may therefore conclude that, so far as it is possible to lay down hard and fast rules regarding so important a surgical procedure—(1) the primary operation should only be performed when the hip joint and upper part of the femur and the soft parts are so disorganised that excision is out of the question and amputation in the continuity is impossble; (2) when the thigh is torn off by a shell, or by a large fragment of shell, close to the hip joint; (3) the intermediary operation should not be performed, as it is nearly always fatal; and (4) that when disarticulation is unavoidable it should, if possible, be done in the secondary period. The records of the American War show that re-amputation through the hip may be performed for osteomyelitis, and other secondary complications, in the portion of the femur left by amputation in the continuity, without the usual high mortality, the death-rate in these cases being about 33 per cent.

The immediate causes of death after amputation at the hip joint are shock, and the hæmorrhage which occurs, almost unavoidably, during the operation, the latter coming, not so much from the main vessels, which can be compressed, from the numerous smaller arteries about the upper part of the thigh.

The methods hitherto employed for the operation have been by antero-posterior flaps and the oval incision; and during its performance by both of these plans the hæmor-

rhage from the smaller vessels above referred to has been very great, so great that the majority have died within a few hours from the consequent shock and anæmia.

Shock and hæmorrhage being, then, the great dangers of disarticulation at the hip, any method which tends to lessen or prevent these complications is strongly indicated. Mr. Furneaux Jordan's plan of disarticulation is therefore the best to employ, as by means of it hæmorrhage and the consequent shock are reduced to a minimum. By the elevation of the limb for some minutes before the operation is commenced, and the application of an Esmarch's tube on the upper part of the thigh, the circular amputation in the lower third can be rendered practically bloodless. All the vessels, large and small, and including the vein, on the face of the circular stump should be carefully secured, and the tube removed. In the enucleation of the femur the larger secondary vessels, the two circumflex and the sciatic arteries, escape division, and the hæmorrhage is extremely slight if the smaller vessels be secured with clip forceps as they are cut. The difficulties of disarticulation at the hip by Furneaux Jordan's method are increased when there is a fracture of the head or neck; but the difficulties of removing the latter portions of the femur are great by any plan when the continuity with the shaft is lost, and do not appertain particularly to the operation here referred to.

Gunshot Wounds of the Knee Joint.

Wounds of the knee joint represent about 3 per cent. of all wounds treated in war hospitals, and of all joint injuries about 28 per cent. will be found to be of the knee. The thinness of the coverings of this joint, and the extent of its synovial membrane, render it perculiarly liable to implication in the injuries produced on the anterior aspect of the limb by projectiles. Periarticular gunshot injuries over the front of the joint, in which the synovial membrane remains intact, are therefore very uncommon; while this class of wound is more likely to be seen on the posterior surface of the leg, and often complicated with wound of the large

vessels and nerves. Simple wounds of the synovial membrane of the knee, without injury to the bones, certainly without fracture, are fairly common; Otis refers to 351 cases of this class.

It is easy to comprehend the occurrence of these simple wounds from bullets traversing the limb from side to side, and passing through the large synovial cul-de-sac beneath the extensor tendon of the leg, without injury to the femur; but the possibility of a bullet passing through the joint even in an antero-posterior direction without injury, or, at all events, without fracture of the bones, has been proved both by actual experience, and by the experiments of Mr. Woods, an American surgeon, and Simon, a German, who showed that, with the leg in any position except one of complete extension, a projectile may enter below the patella, and traverse the joint without fracture of the articular ends, passing through the intercondyloid notch. Again, a bullet entering by the side of the patellar ligament may pass through the joint when flexed, as in this position the tibia and the condyles of the femur are widely separated. Stromeyer and Langenbeck deny the possibility of the occurrence of these injuries. Legouest states that they are extremely rare, and only reports one case during the Crimean Campaign. On the other hand, Otis, as already mentioned, detailed a number of cases; and similar experience was obtained in the war of 1870–71, and in the Russo-Turkish War of 1877. The mortality of all the cases of this kind of gunshot of the knee hitherto recorded has been 21.9 per cent., whereas the cases in which the bones were known to have been implicated, gave a death-rate of 57.3 per cent.

The degree of comminution, when the bones are implicated, varies very greatly, and depends on the velocity of the projectile producing the fracture. Bullets travelling at low rates may merely cause punched-out perforations of the patella without fragmentation; similar clean-cut tunnels may be found in the cancellous structure of the head of the tibia and in the condyles of the femur. But bullets at shorter ranges usually produce extreme comminution of

the patella, and in the larger bones considerable comminution, accompanied by fissuring into their shafts. A bullet passing through the lower end of the femur, between the two condyles, is likely to detach both these processes from the shaft, by fissures extending upwards for three or four inches. The upper end of the diaphysis of the tibia is composed of extremely hard and resistant bone tissue, and is, on this account, subject to considerable comminution and fissuring into the joint when traversed by projectiles at fair rates of velocity. Grooving of the articular ends of the femur and tibia without comminution is a frequent class of bone lesion of this joint.

The diagnosis of wound of the knee presents far less difficulty than that of the hip. Careful consideration of the situations of the apertures of entrance and exit is almost sure to afford sufficiently trustworthy indications as to injury to the joint, and when the limb can be placed in the position it occupied when hit, the inferences to be drawn are almost certain to be correct. The distension of the joint with blood, the pain, the inability to move the knee, and the increased dimensions of the exit wound when the bullet has touched bone, are all valuable signs; displacement of the bony prominences about the joint, crepitation within it on pressure or movement, and general deformity are certain signs.

It has been noticed that simple perforations on the front of this joint have especially the peculiarity of appearing to be merely skin wounds, in consequence of the mobility of the parts over it readily permitting of a want of coincidence in the apertures in the different layers of structure. Wounds possessing this valve-like quality usually heal favourably if no foreign bodies have lodged. Hoffmann gives a mortality of only 23.2 per cent. for injuries of this nature in the war of 1870.

Ability to walk must not be considered to exclude wound of the joint; at the same time, it is hardly compatible with bone injury except of the more simple types. Legouest saw a case in the Crimea where a man was hit on the tubercle of the tibia by a bullet, in which there was dis-

location backwards of the leg without wound of the soft parts or fracture.

The Treatment of gunshots of the knee which has been, for the most part, adopted in war hospitals, even so late as the Franco-German War, was amputation. During the American War 3355 injuries of this joint were observed, and of these, 2431, or nearly three-quarters, were treated by amputation of the thigh or through the knee joint. If amputation at these situations had resulted in low death-rates, this method of treatment might be recommended; but, on the contrary, the mortality of the operation through the joint was 56.6 per cent., and in the lower third of the femur 53.6 per cent. In these days, therefore, a rule for amputation is not admissible. The results of this line of treatment have been far from brilliant; in the Crimea the mortality was 90 per cent. (Spillmann), 76.8 per cent. in Italy (Chenu), 55.1 per cent. in America (Otis), and 59 per cent. in the war of 1870.

The three methods of treatment to be pursued in these cases, according to the degree of severity of the injury, are by conservation, by excision, and by amputation.

Conservative Surgery in the treatment of knee cases, with satisfactory results, has only been possible since antiseptic methods have been applied to them. Septicity is the great cause of death in all joint cases, and in no joint (hip not excepted) have the results of infection of the wound been so disastrous as in bullet wounds of the knee.

During the Russo-Turkish War the first serious attempts were made by Reyher and Von Bergmann to treat gunshot wounds of joints aseptically. Reyher drew a marked line of distinction between what he called "primary" and "secondary aseptic cases," applying the former term to those which had not been examined at the front, nor otherwise interfered with except by the application of a first field dressing, and the latter to those which had been exposed to infection before they reached his hands. Reyher treated 18 "primary aseptic cases" of wound of the knee, simple and severe. Of these, 3 died, or a mortality of 16.6 per cent., in none was excision or amputation per-

formed, and the 15 who recovered had movable joints. The severe cases he irrigated and drained; in the simple ones he purified the exterior only, and applied an antiseptic dressing. These cases were comparable in every way with those which, under other treatment, had produced such high death-rates.[1]

Von Bergmann had equally good results from treatment on the same principles. He selected 15 cases of gunshot fracture of the knee, excluding mere capsular injuries. Of these, 14 recovered, and of the latter 3 underwent amputation, one of them being the only fatal case. An appreciation of the advantages of the strictly aseptic methods, as shown above, over the results obtained by other means in the war of 1870, although some of the latter were more or less antiseptic, may be obtained by a glance at the statistics published by Heintzel. He details 529 cases of gunshot of the knee treated at first conservatively. In 288 cases amputation had afterwards to be performed, giving a death-rate of 78.2 per cent.; of those in which conservative treatment was carried out to the end, 45.2 per cent. died. Of the whole 529 cases treated, 397 died, or a mortality of 75 per cent. Under aseptic treatment Reyher had a death-rate in similar cases of only 16.6 per cent.[1]

The cases which are suitable for treatment by conservation are those in which the capsule only is injured; simple perforations and comminuted fractures of the patella; clean-cut perforations of the condyles of the femur and of the head of the tibia; comminuted fractures of bone or more of the bones forming the joint in which fragmentation and displacement of splinters has not occurred to any great extent; and, speaking generally, those cases in which, while there are perforations and fractures of the articular ends, the degree of comminution and fissuring, and especially of displacement of bone fragments, is not so great as to make it appearent that consolidation of the fracture and firm ankylosis of the joint are impossible or very improbable.

It is extremely difficult to lay down rules for the guid-

[1] Watson Cheyne.

ance of others regarding such a matter as the amount of injury which may be present in cases of fracture, either of joints or of long bones, while the surgeon is still justified in attempting conservative treatment. It is impossible acccurately to define what extent of comminution, what number and extent of fissures, and what degree of displacement of fragments preclude conservation, and necessitate excision or amputation. If it were the case that failure of conservative treatment meant nothing more than a feeling of disappointment on the surgeon's part, and that it included no results of any importance to the patient, this difficulty of making fixed rules as to the kind of case in which conservation is the method to adopt, would be one of little moment. But unfortunately it is not so. It means either that the patient will be exposed to the risk of death from pyæmia and septicæmia if the treatment be persisted in, or that recourse must be had to operative procedures at periods when they may be more dangerous to life than when undertaken as primary operations. Each case, then, must be considered singly, and every surgeon must form and act on his own opinion as to the cases suitable for this mode of treatment.

Cases in which the capsule of the joint alone is wounded, or supposed to be wounded, and in which there is no reason to suspect the lodgment of pieces of clothing or other foreign bodies, should not be explored or irrigated. The wounds and the surrounding skin should be rendered perfectly aseptic, dry, sterile gauze and wool dressings applied, and the limb immobilised.

When the bones of the joint are implicated, the questions of exploration and the removal of loose splinters will always have to be considered, except, possibly, when the patella is the only bone injured. Gunshot fractures of the patella, except at short ranges, are frequently clean-cut perforations; and even where comminution occurs the fragments are likely to be so well held together by the ligamentous and other fibrous structures in connection with them that none will require removal. Moreovcr, they do not always include wound of the capsule. The articular

ends of the femur and tibia are so thinly covered by soft parts that examination externally by palpation will usually supply sufficient data on which to form an opinion as to the necessity of laying open the joint for the removal of splinters; or the exit wound, which is almost certain to be large enough to permit the introduction of the finger, may be utilised for the purpose of examination. Clean perforations of the ends of the bones without comminution require neither exploration nor irrigation, unless pieces of clothing are supposed to have lodged.

When, however, it is evident that considerable comminution has occurred, it will be necessary to make a fresh incision for the purpose of accurate diagnosis, in order to decide the method of treatment to be adopted, and for the removal of such splinters as are quite loose. This incision should be made on one or other side of the joint behind the edge of the patella, as in such a position it interferes least with the integrity of the articulation. If the condition of the fracture is found to indicate conservation, splinters which are detached should be removed, the joint freely washed out with a weak antiseptic solution, and the necessary drainage arranged for, the tubes being left in for not longer than forty-eight hours.

In cases where the comminution of the bones is very great, and where excision may be required, and ankylosis, at all events, is certain to take place, Delorme recommends the anterior curved incision usually employed for excision as being very suitable for the purpose under consideration. This incision opens the joint completely, and gives access to its furthest recesses. By means of it loose fragments can be removed, and, if found necessary, a systematic excision may be performed. If the bullet be lodged and its situation ascertained, it should be removed if possible; but if the difficulties in the way of its removal are insurmountable, on account of the firmness of its impaction in bone, &c., it may be left with less fear of dangerous consequences than may be looked for from the lodgment of other foreign bodies—bits of clothing, for example.

Wounds of the knee joint, when the apertures are

small, are usually accompanied by considerable distension of the large synovial sac within it. If this condition exist, and although there may be no question of the removal of splinters, it will be desirable to make a small incision on one side, and wash out the joint with a weak antiseptic solution, using a drain for the first twenty-four hours. The bandages securing the dressings should exert a firm and equable pressure over the joint, and, in order to obtain this effect most thoroughly, the deeper dressings should be covered with rather large quantities of sterile cotton-wool, the elastic pressure of which is most useful in these cases.

Immobilisation in cases of gunshots of the knee is less difficult to secure than it is in wounds of the hip joint. The movements of the body are so likely to react on the hip that the attachment of the limb to whatever apparatus is employed for immobilisation requires to be very firm in order to prevent movement, and even then absolute rest is most difficult to obtain. This is not so in knee injuries, because any kind of strong splint, applied to the posterior aspect of the leg and thigh, is sufficient to ensure immobility of the joint, and all the more efficiently if the limb be slung, a most necessary practice in these cases. Wire splints, such as that of Roser (fig. 49), are very suitable; a plaster fixation apparatus, interrupted at the knee, or Watson's splint (figs. 50, 51, and 52), as recommended by Esmarch, may be used.

The immobilisation apparatus must extend from the buttock to below the foot, and it should be thickly padded with cotton-wool covered with mackintosh; the padding must be firm, so that it may not be compressed out of shape by the weight of the limb, and attention must be paid to the support required by the joint itself by the use of separate small pads behind the popliteal space. Separate pads must also be used behind the ankle joint to keep the point of the heel quite free from pressure against the main pad of the splint, otherwise pain will arise, and, if this condition be allowed to continue, sloughing of the heel is certain to occur. The assurance of the patient that

his heel "feels quite comfortable" is not sufficient; the surgeon must himself ascertain that the immediate point of the heel is not in contact with the padding of the splint,

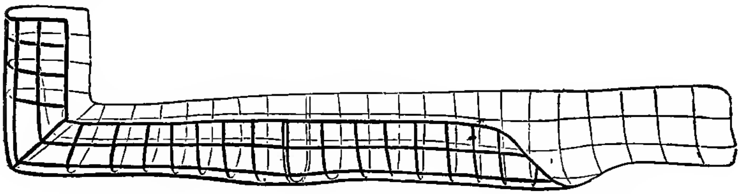


FIG. 49.—Roser's Wire Splint for Gunshots of the Knee.

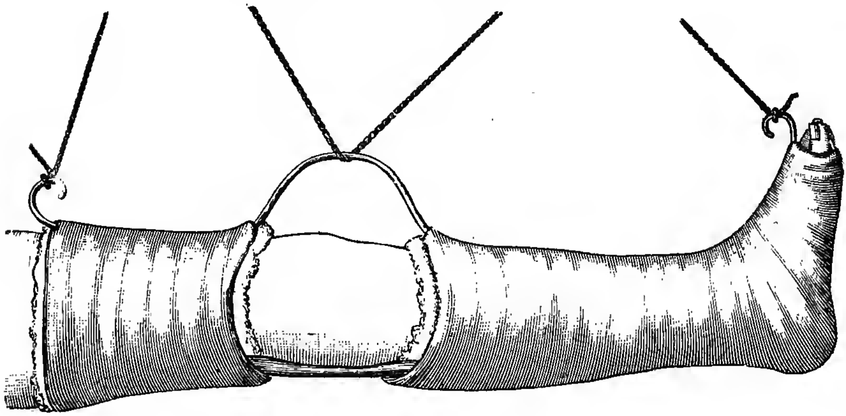


FIG. 50.

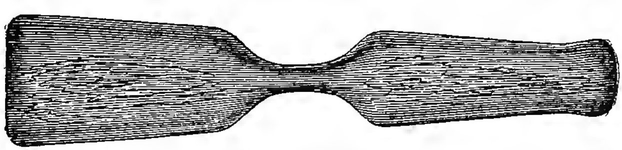


FIG. 51.

FIGS. 50, 51, 52.—Watson's Suspension Splint for Gunshots of the Knee.

and that the weight of the leg is distributed on the calf muscles and the Achilles tendon. We must remember that apparatus for immobilisation may have to be worn for many weeks or months, and that an ill-nourished part like

the heel will not bear pressure without giving way. Whether the apparatus be composed of wood, or of zinc or wire netting, it is of advantage that it should have vertical side pieces for the thigh and leg, hinged, or otherwise movably attached to the back splint, but interrupted for about eight inches at the sides of the knee to enable the wound to be redressed without undoing the bandages completely.

The position in which these cases are usually put up is one of full extension of the leg upon the thigh; but if the degree of injury be such that recovery with ankylosis of the joint is the best that can be hoped for, a position of very slight flexion at the knee will be found to give better results in walking. The limb should be suspended by any of the usual means, and the higher the point of attachment of the suspension apparatus is, the greater will be the comfort of the patient, and the less the liability to displacement of the fractured bones.

If the case proceed satisfactorily and remain aseptic, after ten days or a fortnight, more permanent fixation may be employed by using plaster of Paris bandages, instead of the ordinary ones, for the purpose of attaching the leg and thigh to the splint; these, of course, should not encroach on the situation of the wound, the bandages and dressings of which must always be left separate from the rest of the apparatus.

If the joint should suppurate, a lateral incision must be made into it, and very thorough disinfection be carried out by irrigation with 1–20 carbolic or 1–1000 sublimate solution, and drainage arranged for. If any loose splinters are perceived, they should be removed. A drainage tube in a more dependent situation is of great advantage under these circumstances, and to introduce it, a long sinus forceps should be passed into the joint through the lateral incision, and made to point at the outer side of the popliteal space, when it should be cut down upon and a tube placed within its jaws; the drain can then be drawn into the joint. When it has been found necessary to open the joint in this way, irrigation should be practised daily.

If this treatment does not succeed, and the suppurative process is not checked, and the patient shows signs of absorption of his own septic fluids, the best treatment to adopt is amputation in the lower third of the thigh.

As regards the Final Results of successful conservative treatment of gunshots of the knee, in cases where the comminution is severe, where splinters have to be removed, and where, possibly, fresh incisions have to be made into the joint, the best we can expect is recovery with ankylosis in good position; and this result is a most satisfactory one considering the nature of the injury. Cases in which the synovial membrane only is wounded, cases of fracture where the bone is clean pierced or only grazed, and cases where the comminution is very slight, should recover with perfect, or almost perfect, movement retained, but only if suppurative arthritis be avoided. The successes of Reyher and Von Bergmann in the Russo-Turkish War warrant the latter prognosis. But suppuration within the joint, if it does not necessitate amputation, will surely end in partial or complete ankylosis.

Excision of the knee joint for gunshot fractures has, up to the present time, given such bad results and afforded such high death-rates that the operation has been almost universally condemned. Sir William MacCormac[1] remarks of excision that "it may be performed in civil practice, but is not justifiable in military." Legouest[2] concludes that "we doubt that resection of the knee can ever be substituted in a general way for amputation of the thigh in military surgery"; and Otis, that it should only be done in war when the patient refuses amputation. Ashhurst[3] declares that "excision of this joint should be banished from the practice of military surgery." Quotations to a similar effect might be multiplied almost without limit.

But, on the other hand, Langenbeck, Delorme, Czerny, Socin, Nussbaum, and others hold that already some satisfactory results have been obtained by this operation, and

[1] "Notes and Recollections of an Ambulance Surgeon."

[2] *Traité de Chirurgie d'Armée.*

[3] "Principles and Practice of Surgery."

believe that, in the future, under modern methods of dressing wounds, it will displace amputation in the thigh, except in cases of the most severe disorganisation of the joint, and wound of the large vessels and nerves.

During the American War fifty-seven excisions of the knee were done, with a mortality of 81.4 per cent., which is 30.3 per cent. greater than that following amputation in the thigh for wound of the knee. In the Austro-Prussian War of 1866 the mortality was 86.6 per cent.; in the Schleswig-Holstein Campaign it was 85.7 per cent.; in the Franco-German War it was 80 per cent., and in the Russo-Turkish War of 1876–77 it reached 100 per cent. With only these terrible data to judge from, it is not to be wondered at that some of the best surgeons pronounced against the operation in military practice in the field. But in these wars nearly all the wounds suppurated, and suppuration of gunshots of the knee usually means death or amputation. In future, with an ample supply of efficient antiseptic materials, and a full knowledge, on the surgeon's part, of the *technique* of the modern system of wound dressing, these cases, instead of giving rise to foul discharges for months, and killing the patients by septicæmia and pyæmia, should heal by first intention; but to obtain this result, it is hardly necessary to mention that transport of the patients is not to be thought of.

The cases which require primary excision are those in which there is considerable comminution of the bones of the joint, where loose fragments are so numerous that considerable loss of bone substance results from the operation for their extraction, and where, consequently, firm consolidation and ankylosis cannot be expected to occur. Delorme is of opinion that we need not fear to excise as much as three inches of the tibio-femoral articulation when this procedure is indicated by the condition of the fracture; and that it is especially in fractures of the condyles of the femur, below the upper line of the cartilage, that this operation is most useful. Lesions of the upper epiphysis of the tibia are, he declares, "usually either too limited or too extended to be suitable for excision."

Intermediary and Secondary Excisions of the knee have but little place in military practice. Judging from the analogy of the conditions requiring these operations in other joints to those which might be supposed to suggest them in these cases, they would be indicated, the former, at the outset of infection and suppuration in the wound, and the latter for persistent suppuration, arthritis, and osteitis. But in view of the really important end to be desired, the preservation of the patient's life, amputation may be looked to for better results under the circumstances indicated.

The best mode of operating is by means of the horseshoe shaped incision, commencing at the level of one condyle and ending at the other, the lowest point of which is close above the tubercle of the tibia. The after-treatment is similar to that used when conservation is being attempted.

The Results of Excision of the knee, when recovery takes place and deviation of the opposed bones is prevented, are good. In other joints recovery with ankylosis may almost be considered a failure in treatment, but in this case it is a distinct success. Nevertheless, in capsular injuries, and where the comminution is of the minor degrees, normal or nearly normal motion should be retained in the absence of suppurative infection. Gurlt's statistics of the last four German wars give 5 results as "very good," 3 as "good," and 1 as "very bad," out of 9 operations performed. Otis details a case of resection of the knee, the subject of which afterwards "could not only walk almost as well as ever, but could even dance round dances," although one and a half inch of the condyles of the femur, and one inch of the tibia and the patella, had been removed.

Primary Amputation, either through the joint or in the lower third of the femur, is required in cases of extremely comminuted fracture of the bones of the joint, usually produced by fragments of shell, but occasionally by small-arm projectiles at short ranges; in cases where the leg is torn off, or nearly so, close to the knee joint by fragments of

shell or the bullets of case-shot; and in cases where the main vessels or nerves are wounded—but instances of the last class seldom survive long enough to reach a field hospital. If the lower end of the femur escapes injury, and if sufficient soft parts remain intact to satisfactorily cover the stump, the operation may be done through the joint, as the shock is less, and the stump left is an excellent one. The mortality of this operation in the American War was 53.2 per cent. But we must, however, remember that there is some evidence from statistics that amputation through the lower third of the femur for gunshots of the knee, gives a slightly better prospect of life; in America the latter class of cases gave a death-rate of 51.1 per cent. The operation in the thigh is the simpler, and there can usually be no difficulty in obtaining covering for the stump.

The indications for intermediate and secondary amputations have already been alluded to under the heading of excisions of the knee at similar periods, and need no further discussion.

Gunshot Wounds of the Ankle Joint.

Gunshot wound of the ankle is a class of injury which, although not very fatal of life, is peculiarly liable to be followed by loss or great impairment of the functions of the joint. Traversed as it is in front by a large number of tendons, section of which, and adhesions within the sheaths of which, are so commonly the results of gunshots, it is especially exposed to conditions which, when recovery takes place, interfere with its normal movement. Ankylosis of the joint itself is a frequent consequence of fracture of the bones forming it, and adhesions between the tendons and their sheaths are very liable to form, even when suppuration in their vicinity has been prevented by the methods of treatment employed.

Periarticular injuries, and wounds of the synovial membrane only, are seldom met with in gunshots of the ankle joint, in consequence of its superficial position and the ac-

curacy with which the bones forming it fit into each other. When the bullet strikes the lower end of the tibia, it usually produces a clean-cut perforation of the cancellous structure acccompanied by extensive fissuring into the shaft. When the astragalus is perforated, the comparatively soft bone tissue of which it is composed is broken into numerous small pieces; it is, in fact, pulverised to a greater or less extent according to the velocity of the projectile. The fibula, in consequence of its extreme hardness, is subject to considerable comminution and fissuring when implicated in a gunshot fracture. Besides the injuries to the three bones actually entering into the formation of the joint, other bones, and the joints of the tarsus, may be included in gunshot wounds of the ankle joint; and the difficulties of preserving the functions of the foot and ankle in these cases depend to a large extent on this fact.

Treatment.—The great majority of army surgeons, even so lately as the time of the American War, treated gunshot wounds of the ankle by amputation in the leg or disarticulation at the joint. The surgeons during the American War treated more than two-thirds of their cases by these methods. This was in accordance with the views of Thomson, Hennen, Guthrie, and many others.

Of the three methods of treatment usually considered applicable to joint cases, conservation, excision, and amputation, almost all surgeons even now agree that the systematic operation of excision affords most unsatisfactory results. It is followed by a greater mortality than either of the other methods; secondary amputation is frequently required after its employment, in consequence of pain in the joint and necrosis of the bones in its vicinity; and, even when these complications do not occur, and recovery so far as is possible takes place, the functions of the joint in walking are but indifferently performed.

The great extent of fragmentation and fissuring which projectiles produce in the tibia and fibula necessitates the removal of much of these bones, and ankylosis in good position is unlikely to be secured.

Conservative Treatment is the method to employ in the

great majority of gunshots of the ankle. During the American War 1711 cases of gunshot wound of the ankle were recorded. Of these, only 518 were treated conservatively, and none but the slighter cases were selected for this method; the mortality was 19.5 per cent. The experiences of the American surgeons during the earlier periods of the war gave them no encouragement to depart from the teaching of Guthrie as to the proper procedure in ankle cases, and accordingly amputation in the leg or at the joint was carried out in over two thirds of them. In no class of joint wounds are antiseptic methods more necessary than in those of the ankle; it is therefore probable that the treatment by amputation pursued by the American surgeons in times before these methods were in common use really resulted in a saving of life. But in future, as above stated, conservation will be indicated in the large majority of gunshot injuries of this articulation—indeed, in all except those in which the bones and soft parts about the joint are so crushed and disorganised as to leave no other method for consideration but the immediate removal of the limb above the site of injury.

With an aseptic condition of the wound, all the difficulties of conservation will disappear. Arthritis, necrosis, osteitis, and all the other complications which have hitherto so frequently demanded secondary amputations, will no longer supervene, to make the surgeon regret that he did not employ primary amputation at the outset. The functions of the joint, too, will more often be retained; for these same complications are the causes of interference with its usefulness after recovery.

The degree of fracture should be ascertained by examination through the wound of exit, which will usually be large enough for this purpose; if not, it may be slightly extended, care being taken not to cause further injury to the tendons passing over the joint. All loose fragments should be removed, irrigation thoroughly performed, and a drain placed in the joint for the first twenty-four or forty-eight hours. The astragalus is peculiarly liable to undergo extreme comminution from the passage through

it of a small-bore bullet at a high rate of velocity. I published, in the *British Medical Journal* of 2nd June 1894, an account of the injury produced in the ankle joint of a recently amputated leg, by a Lee-Metford bullet at fifty yards range. "The bullet passed through the astragalus about half an inch below the articulating surface for the tibia. The astragalus was completely pulverised, with the exception of its head, and all its articulating surfaces were split except that for the scaphoid" (fig. 27, p. 117). No useful reparative process could take place in a case of this kind under treatment, and Delorme recommends that, when this bone is much comminuted, it should be removed through a fresh incision on the outer side of the joint. In the less severe cases, also, of fracture of the astragalus, the loose pieces of the bone should be removed; for the process of destruction it undergoes from the action of a bullet is pulverisation rather than mere comminution, and the bone-grit or dust into which it is reduced cannot be expected to consolidate, but must act as a foreign body until thrown off by the tedious operations of nature. Small loose fragments of the lower ends of the tibia and fibula may be extracted through small incisions over them; but when comminution in these bones is extensive, amputation will probably be required.

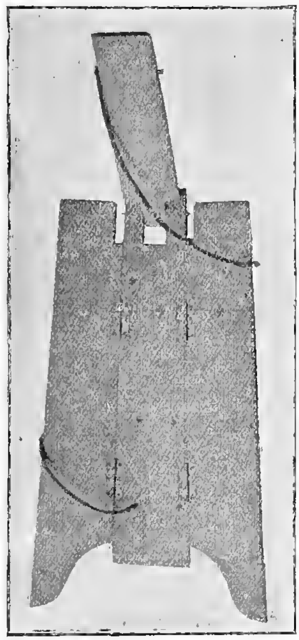


FIG. 53.
Box-splint, open.

The numerous tendons passing over this joint are very liable to be severed by bullets, and when this occurs, every care should be expended in reuniting their cut ends by aseptic catgut or thin silk sutures. The wounds and the

skin of the leg and foot should be rendered aseptic by washing and irrigation with 1–40 carbolic lotion, and dry dressings of gauze and wool applied.

The Immobilisation of the joint is not difficult to provide for: any fixed apparatus which includes the leg from the knee, and gives lateral support to the foot, while it also keeps it strictly at right angles to the leg, will be suitable. The old "box splint" (figs. 53 and 54), having a movable foot-piece, and the sides hinged to the posterior part so as to let down for the dressing of the wound, is

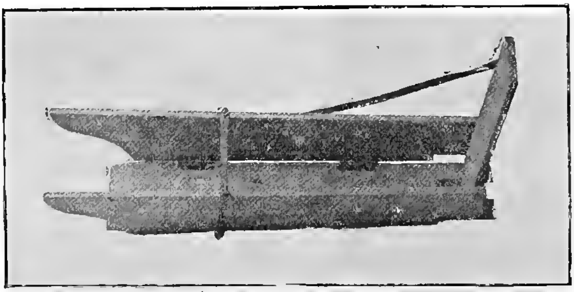


FIG. 54.
Box-splint, with sides and foot-piece in position.

very efficient; or Esmarch's plaster suspension splint (fig. 55) may be used. In any case, the limb should be suspended. If suppuration supervenes, incisions must be made into the joint wherever they appear to be most required; disinfection of the joint should be attempted by means of the more powerful germicide solutions; drainage should be provided and maintained, and irrigation practised once or twice a day.

As regards the results of conservative treatment, ankylosis may be expected in the large majority of cases, but ankylosis in good position may be considered a satisfactory result. In the cases where the bone injury is slight, the motions of the joint may be retained more or less completely, in the absence of infection of the wound.

Excision of the Ankle.—The results of primary excision of the ankle for gunshot injuries cannot be said to recom-

mend the operation. While it does not succeed in saving life, it can hardly be considered successful in preserving limbs, for if they are retained it is only at the expense of their utility. The mortality after excision is greater than that following on amputation, either in the leg or at the joint; and the functions of the foot are, as a rule, so badly performed, that walking with an artificial substitute after amputation is easier. Otis concludes that, "while the ju-

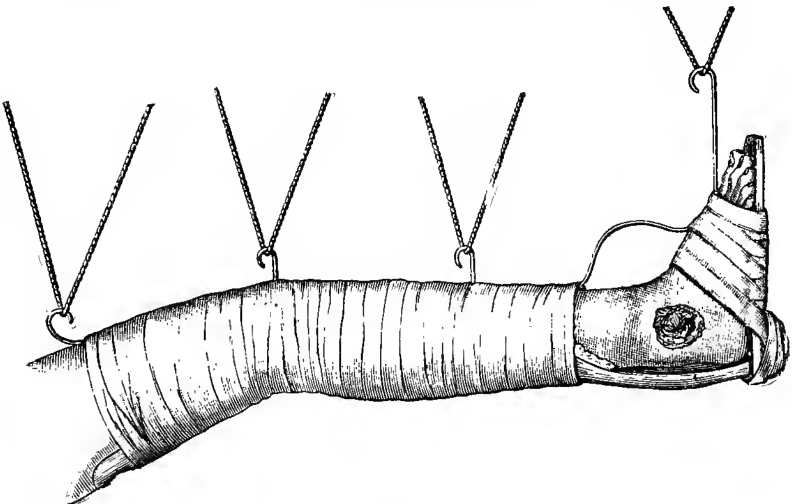


FIG. 55.
Esmarch's Suspension Splint for Gunshots of the Ankle.

dicious use of the gouge and bone forceps is admissible in gunshots of the ankle, the formal excisions are rarely successful." Excision is especially contraindicated when the tibia and fibula are severely damaged; removal of the injured astragalus has been already alluded to.

As a secondary operation, excision may sometimes be undertaken for prolonged suppuration, arthritis, and necrosis; but the majority of these cases will be more satisfactorily treated by amputation in the lower third of the leg.

Amputation as a primary operation is required in all cases of severely comminuted and extensive gunshot fractures of the ankle, and more especially where the injury

to the tibia and fibula consists of fragmentation and prolonged fissuring into the shafts of the bones. When the tibia and fibula are uninjured, and the astragalus and perhaps other of the tarsal bones only are implicated in the fracture, the operation should be done at the joint, if the condition of the soft parts permit of this procedure.

During the American War 161 amputations were performed at the ankle joint, with a mortality of 25.1 per cent., or 2.5 per cent. less than that of amputation in the lower third of the leg In the same war the secondary operations gave a mortality of only 7.7 per cent.

Syme's operation is the best method to employ, as it gives a better stump for the application of an artificial apparatus, and the method of performing it by peeling the soft parts off the os calcis from above downwards, *after disarticulation* of the ankle, is far easier than that usually described in text-books.

Delorme suggests the propriety of amputation in cases where the lesser degrees of bone injury are accompanied by destruction of the posterior tibial nerve. When the soft parts about the joint are so much damaged that efficient covering for an amputation at the ankle cannot be obtained, and when the ends of the tibia and fibula are comminuted, the operation must be done in the leg; but the site of the section must be determined by the extent of fissuring, and no more should be removed than is necessitated by this condition.

Secondary Amputation is indicated when conservative treatment has failed in consequence of infection of the joint, and the patient is losing ground from suppurative arthritis and necrosis. The mortality, as above mentioned, is small. These operations should be performed through sound tissues, clear of the suppurative process.

GUNSHOT WOUNDS OF THE FOOT.

Gunshot wounds of the foot are a class of injury which it is difficult to treat with satisfactory results. Necrosis and exfoliation of the fractured bones, prolonged useless-

ness of the injured part, flattening or complete loss of the arch of the foot, and ankylosis of the ankle or tarsal joints are the conditions which are so liable to occur in these cases, and to make the results unsatisfactory from interference with the functions of the limb in walking. The complicated mechanism of the articulations of the foot, the peculiar manner in which one synovial membrane covers many joints, and the close relationship of the bones and joints to each other, make it probable that the injury caused by a bullet will not be confined to the bone or joint immediately traversed by it; and, for the same reasons, when infection occurs, suppurative inflammation is likely to be widespread. The mortality of gunshots of the foot during the American War was 8.3 per cent., in the war of 1870–71 it was 7.8 per cent., and in the Russo-Turkish War 3.6 per cent.

In the Treatment of gunshots of the foot, conservation will be the method to employ in the very large majority of cases. When the destruction of soft parts and bone is very extensive—as in injuries caused by large projectiles or their fragments, or by small-arm bullets at close ranges—primary amputations will be required, and Hey's tarso-metatarsal or Chopart's medio-tarsal operation should be performed according to the extent and situation of the injury done; while in the still more severe cases disarticulation at the ankle by Syme's method may be required. Other primary operations are seldom indicated, and, when performed, give high death-rates. Small-arm bullets, except when travelling at extreme velocities, do not usually cause such destruction to tarsal bones as to afford indications for primary excisions, and the results, either towards saving life or preserving useful limbs, are not satisfactory. In America conservation gave a mortality of 4.1 per cent., excision 19.3, and partial amputations of the foot 18.9 per cent.

Secondary Excision of any portion of the foot may occasionally be required for the removal of centres of suppuration and of necrosed bones. Once infection of these wounds supervenes, hope of recovery without operative

interference may be abandoned, and under these circumstances secondary extraction of the fractured bones, combined with careful and complete disinfection of the wounds and free drainage, gives satisfactory results.

In cases of injury to the hand, no remnant of a finger or thumb should be sacrificed, if with care it can be preserved, even in a deformed and partially ankylosed condition; any portion of the hand which can be saved to a patient will be of value in after life. The reverse obtains in injuries of the toes; an ankylosed toe, or one certain to become so, should therefore be removed, as its presence is only a cause of pain and difficulty to its possessor in walking.

When conservative treatment has been determined on, no exploration of the wound need be made, unless the operation of extraction of splinters be necessary. The part should be thoroughly asepticised, the wounds occluded by the usual aseptic gauze and wool dressings, and the limb and foot, including the toes, put up in an immobilisation apparatus. Nothing can be more suitable for this purpose than the old fracture box already alluded to (see page 224); with its use, deviation of the foot from its proper position is impossible, the wounds can be redressed without difficulty, and it is readily prepared from the boards of old packing-cases or other similar materials. The foot should be placed at right angles with the leg, the point of the heel being quite free from pressure, and the limb should be slung with the knee joint slightly flexed. Plaster of Paris, and zinc fixation apparatus are also very suitable for immobilisation after gunshots of the ankle and foot.

Hæmorrhage from the large vessels traversing the sole of the foot is a serious and a fairly common complication in these cases. Delorme strongly insists on the absolute inutility of any other treatment than ligature of both cut ends of the vessel when the plantar arteries are wounded. Ligature of the anterior and posterior tibials exposes the patient to the almost certain occurrence of secondary hæmorrhage, in consequence of the free anastomoses of these vessels, and the possible supervention of gangrene of the

foot. When only the smaller vessels are injured, pressure by means of an antiseptic tampon, or a thick pad of antiseptic gauze, may be sufficient. When performing the ligature of the vessels of the plantar arch, the bloodless method should be employed, the leg being elevated for some minutes, and an Esmarch's elastic tube applied before laying it down.

CHAPTER VIII

GUNSHOT WOUNDS OF THE DIAPHYSES OF LONG BONES

Contusions of the shafts of the long bones, with penetration of the soft parts, but without actual fracture, are injuries which occasionally give considerable trouble in treatment, and are followed by consequences of a grave nature. They are referred to in the records of all wars; but it has only been since Stromeyer first drew attention to their importance, and since Lidell, in America, and Beck, Socin, and others in Europe, recorded their experience of these apparently trivial cases, that they have received the attention in their management which they deserve.

When smooth-bore muskets were in use, it was a fairly common occurrence for their soft leaden bullets, when travelling at low velocities, to be arrested and flattened out by contact with the shafts of long bones, producing thereby severe contusions, though, perhaps, no actual fractures (fig. 56). This is unlikely to happen with the modern small-arm projectiles; but mere contusions of bone may still occur with the new bullets when they graze the bone in passing. The merest touch of a bullet at a high rate of velocity is often sufficient to produce a transverse fracture of a long bone an inch or two away from the point of impact, but this does not necessarily always happen, and it is unlikely when the bullet is travelling at a low rate; but the contusion of the bone, unaccompanied by fracture, may be severe from a graze of this kind.

During the American War only 22 cases of this class of injury to the humerus were recorded. None of them required operative treatment, but they gave a death-rate of 18.1 per cent. There were 162 shot contusions of the femur, 9 of which necessitated secondary amputation, with

a mortality of 77.7 per cent., while the conservative treatment of the remainder only gave a death-rate of 22.8 per cent. The most common causes of death were pyæmia and osteomyelitis.

When the periosteum of the diaphysis of a long bone is severely contused, but not torn, by a projectile, blood is immediately effused beneath it, and its separation from the bone, over a more or less extended area, occurs. The bone at the point struck is therefore deprived of some of its blood supply, and a condition of tension on the bone surface is set up; besides this, the shock to the bone itself, although no fracture be produced, may cause some crushing inwards of its superficial layers, and therefore some interference with its circulation, a condition eminently suitable for the growth of bacteria if they should gain access to the site of injury. When the periosteum is torn in these cases, one of the predisposing causes of suppuration, the tension on the bone surface, is wanting.

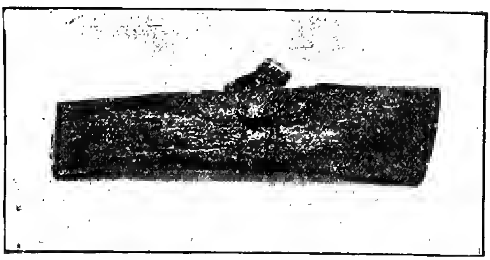


FIG. 56.

Conoidal bullet flattened against femur.—*Netley Museum.*

As a rule, cases of contusion of the diaphyses should recover in a satisfactory manner, and will invariably do so if infection of the wound be prevented. But with the advent of micro-organisms at a situation where the tissues are so ill prepared to oppose their action and combat their deleterious effects, complications of the most grave character are certain to supervene. When suppuration occurs in these cases, pain, swelling of the limb, and elevation of temperature will be observed; these symptoms are evi-

dences of periostitis and osteitis, inflammatory conditions which, without active and immediate treatment, will proceed to chronic inflammation of the bone with necrosis and exfoliation of sequestra, circumscribed abscess of bone, suppuration within the medullary canal, and septic osteomyelitis. These are the complications which necessitated the 9 amputations of the thigh with only 2 recoveries in cases of this class during the American War. The dangers of these cases have to be especially insisted on, for the reason that the injuries appear so simple. An uncomplicated wound of the soft parts leading down to the bone, with lodgment of the bullet, or two small apertures in the skin, with the bullet track in the immediate vicinity of the bone, unaccompanied by fracture, do not at first sight appear to be of very serious import. Nor are they so if infection be prevented; but with contamination of the wound with bacteria the patient's life and limb will be in imminent danger.

The Treatment of Contusions of the long bones should be carried out with such care and attention as will ensure the healing of the wounds in a perfectly aseptic manner. Perfect disinfection of the skin for a considerable area about the wound, and of the wound itself, should be rendered certain. If the bullet has lodged, it should be removed, and enlargement of the entrance wound for this purpose will probably be necessary. If extraction of the bullet has been required, thorough irrigation of the bullet track with a weak antiseptic solution should be performed, and the wound closed with dry gauze and wool dressings. If the bullet has only grazed the bone and passed out, irrigation is hardly required, unless pieces of the clothing have been carried in, and the clothing at the entrance side should be carefully inspected in order to ascertain the probabilities for and against this having occurred. If shreds of clothing have been carried into the wound, they should be removed if possible; but their recognition by the finger in the course of a bullet track is most difficult, unless the pieces are large, and even then they may escape detection.

When the wound has been attended to, the limb should

be immobilised by any means suitable to the particular case; the forearm should be flexed at a right angle in a sling, and bound to the chest wall, if the injury be in the upper extremity, while, if the injury be in the lower extremity, the limb should be placed in a position of almost complete extension. If the wound runs a satisfactory course, the immobilisation apparatus should not be left on too long. Ankylosis of the joints of the limb is liable to occur from a too prolonged immobilisation, and must be guarded against by passive movements and massage.

When the complications already referred to are setting in, they will be indicated by pain and swelling of the part and a rise of temperature. Under these circumstances there must be no delay in entering upon their active treatment. There should be no waiting for the formation of pus and its evidence by the perception of fluctuation. An incision, at least three inches in length, must be made down to the bone, laying open the periosteum to a like extent, and the wound disinfected by means of one of the more powerful antiseptic solutions. If pus be given exit to by this procedure, improvement may begin immediately; but if not, and if the pain and high temperature persist, the medullary canal must be opened by means of a suitable trephine, in order to give exit to a circumscribed abscess of bone, or to the products of suppuration within the bone cavity itself. The trephine may be used with advantage at even more than one point. Treatment on these lines will usually have the desired effect; but occasionally it will fail, and failure may be looked upon as pointing to a condition of septic osteomyelitis, the only hope of recovery from which is afforded by amputation at the joint next above the site of injury, or as near to it as possible.

Fractures of the Diaphyses of Long Bones.

The kinds of injuries to the bone usually met with in gunshot fractures of the shafts of long bones have already been described in a former chapter. The amount of dam-

age done in a particular case depends directly on the velocity with which the missile is travelling at the moment, and on the resistance offered by the bone to its passage. As these conditions are marked in degree, so will be the extent of the comminution, the displacement of the fragments, and the length of the longitudinal fissures and their number. All degrees of comminution and fissuring are to be expected in gunshots of the diaphyses, from mere grooving of the side of the bone by the graze of a bullet, or crushing in of the bony wall on the entrance side by one nearly spent, to fractures showing extreme fragmentation of the shaft into large and small pieces, accompanied by more or less fissuring, which occasionally is so severe as to extend into the joints both above and below the immediate point of impact. The number of these cases admitted into the field hospitals after an action is usually very large, Fischer placing the ratio of fractures of the diaphyses at 12 per cent. of all wounds. The comparative frequency of the occurrence of gunshot fractures of the different long bones is recorded by Otis, during the American War, as being as follows: in the bones of the leg, 31 per cent.; humerus, 28.4 per cent.; femur, 22.6 per cent.; and in the bones of the forearm, 17.9 per cent. These ratios are irrespective of gunshots implicating the joints.

The Treatment of Gunshot Fractures of the Humerus.—During the American War 7888 cases of gunshot fracture of the shaft of the humerus, of which the final results were ascertained, came under observation. Of these, 2960 were treated conservatively, with a mortality of 14.3 per cent.; but only the slighter cases were subjected to this method, because, at that time, little hope of recovery was held to be afforded by it in the more severe ones. Excision of the broken ends of the bone was performed in 696 cases, with a mortality of 28.5 per cent.; and amputation was performed in 3685, with a mortality for the operation at all periods of 23.6 per cent.

Excision in the Continuity of the shaft of the humerus has not been practised in any war to as large an extent as it was by the American surgeons in the War of the Rebel-

lion. Cases treated by a systematic operation of excision in the continuity of the humerus, as of other long bones, have been comparatively exceptional in other campaigns, and the conclusion to be drawn from the experience gained in America is one which will tend to render its employment still more rare in future. The operation is condemned on all sides, even its most zealous upholders in America now pointing out its disadvantages. Ashhurst writes of excision in the continuity of the humerus, that "it is more fatal than amputation at the same situation." Hamilton says, "There is no well-grounded hope that union will occur; it should only be employed as a last resource"; and S. W. Gross states, that "it is unnecessary and dangerous." Otis sums the subject up by saying: "I cannot discern that the experience of the war lends any support to the doctrine of the justifiability of the operation, except in very exceptional cases." The mortality following it was 28.5 per cent., double that of conservative treatment, and 12 per cent. more than that of primary amputation in the upper third. Schwartz, after the Schleswig-Holstein and Danish wars, wrote: "Resection in the continuity of the humerus is to be rejected." MacCormac is no less decided in his opinion: "Primary resection of the extremities of the fracture should never be performed; it leads to delayed union, false joint, or sets up osteomyelitis and necrosis." [1]

The only cases where it might, at first sight, be considered that excision is indicated, are those in which the immediate site of the fracture is completely cleared of bone tissue, and there is loss of substance between the fractured ends for two or three inches. In injuries of this class the excision of the uneven ends of the bones might be looked upon as sound practice, but it has been proved to be otherwise. Fractures with extensive loss of substance are exceptional; moreover, they are always the results of bullets fired at short ranges, and the damage is likely to be so great as to necessitate primary amputation rather than any other method of treatment. When excisions are per-

[1] Heath's "Dictionary of Surgery."

formed, secondary amputations have frequently to be done later; false joint is a common result; and they kill more patients and less often preserve useful limbs than does the conservative method.

Primary Amputation is an operation which is seldom indicated in gunshot fractures of the humerus. Guthrie considered that it is hardly ever required in these cases. Legouest says that even with wound of the brachial it may not be necessary to amputate. In the Crimea, according to Matthew, it was "only done under the most desperate circumstances." Longmore held similar views. In America the operation was employed far too often, only the least severe cases being treated conservatively.

The indications for primary amputation through the humerus do not depend on the degree of comminution and fissuring of the bone, but rather on the amount of destruction of such important soft parts as the large vessels and nerves of the arm. Even in pre-antiseptic days, failure of union of the most severely comminuted gunshot fractures of the humerus was uncommon, and now, with the means of preventing suppuration in our hands, it should be more so: consolidation of the fragments should take place, however numerous the pieces may be, if the blood supply of the limb has not been too greatly interfered with by laceration of the brachial artery. Most military surgeons have recommended amputation when the brachial is wounded; but now it is beginning to be recognised that as an indication for primary amputation the *situation* of the wound in the vessel is the important point, rather than the mere fact of its being wounded. Chauvel and Nimier, Legouest, Delorme, and others are of opinion that if the brachial artery be severed so low down as not to interfere with the supply from the superior profunda, primary amputation should not be done, but a careful watch should be kept for the first signs of the occurrence of gangrene. Delorme would do a primary amputation in cases where, although the brachial is wounded below the origin of the superior profunda, the anastomotica magna is also wounded. According to these authorities, wound of the brachial so

placed as not to interfere with the anastomosis of these two branches does not indicate a necessity for immediate amputation: both ends of the wounded vessel should be tied in the wound, and gangrene watched for. This doctrine may be sound so far as it goes, but the difficulty will always be, in the comparative hurry of field surgery, to diagnose these cases with the necessary accuracy, to determine whether or not these vessels are lacerated when the bullet tracks lie in the immediate vicinity of their origins or of their courses.

No doubt, cases of gunshot fracture of the humerus accompanied by wound of the large vessels and nerves do recover; but, on the whole, unless the circumstances be very favourable as regards nursing, and an almost undivided surgical supervision of the case, it will be safer to amputate under the conditions referred to.

The general indications, therefore, for primary amputation for gunshots of the humerus may be summed up as depending, not on the degree of bone comminution, but on the amount of destruction of the soft parts, and on the interference with the circulation and sensibility of the limb produced by wound of the main vessels and nerves. When the injury occurs high up, and these structures are implicated, there need be no hesitation as to the propriety of the operation; when the wound is lower down, below the origin of the superior profunda, an attempt to save the limb *may* be made, but it will probably fail from the supervention of gangrene, on the first sign of which an amputation should be performed. Primary amputation is also required when the limb is found to have been removed, or nearly so, or greatly disorganised by large projectiles or their fragments.

Secondary Amputation is indicated for secondary hæmorrhage which may not be amenable to other treatment, and for the consequences of infection and suppuration of the wound, osteitis, necrosis, and failure of consolidation of the fracture, as well as for the removal of a useless and painful limb dependent on implication of the large nerves. When septic osteomyelitis supervenes, disarticulation at the shoulder should be immediately performed as the only

means of saving life; and if symptoms of pyæmia have not previously set in, the prospect is not hopeless, though it is certainly not good.

The Method to be employed may be by lateral or antero-posterior flaps, or, in muscular arms, by the circular or modified circular operation.[1] As regards the situation at which the operation should be performed, the statistics of the American War clearly showed a smaller death-rate for amputations done in the middle third than that following the operation in the upper or lower thirds. Primary amputations in the upper third gave a death-rate of 13.6 per cent.; middle third, 12.3 per cent.; and lower third, 27.7 per cent. Otis suggests no sufficient reason for this fact; but the same relation was observed whether the operations were primary, intermediary, or secondary. This may, in part, have depended on the fact that many of the operations in the lower third were performed for wound of the elbow joint, the same thing being observed in amputations done for wounds of the ankle and knee. The American statistics notwithstanding, when the choice of situation for an amputation is an open one, no more of the limb than is absolutely necessary should be removed.

Conservative Treatment.—From what has already been stated regarding excision and amputation, the class of cases of gunshot fracture of the shaft of the humerus which is suitable for the conservative method may be fairly well inferred. The results of excisions in the continuity of the shafts of long bones have proved beyond any doubt that the operation is not justifiable from any point of view; the exceptional circumstances under which primary amputations may be required have been already detailed. All cases, therefore, which do not come under the latter category should be treated conservatively. When the channels for the principal blood and nerve supplies of the arm have not been destroyed, comminution need hardly be considered. With careful attention to antiseptic *technique*, and with the wound running an antiseptic course, consolidation of the fragments, howsoever numerous they prove to be,

[1] Erichsen.

may be expected almost with certainty. Splinters which preserve only slight adherence to the surrounding soft parts, though a good deal displaced, when returned as nearly as possible to their normal positions, become included in the callus, and are not thrown off as foreign bodies, if suppuration be prevented. If the fracture be high up, the fissures may not cause implication of the shoulder, as they probably cease at the anatomical neck. Extension by fissuring into the elbow, when the injury is in the vicinity of this joint, is much more likely to occur; but in neither case is this condition a contra-indication to an attempt to save the limb, nor is it likely to interfere with its success to any great extent.

The procedures to be carried out in the conservative treatment of gunshots of the humerus are similar to those recommended in other bone injuries: the asepticisation of the skin and of the wounds; the examination of the fracture; the removal of detached splinters; the restoration of large displaced fragments which still adhere, as nearly as may be, to their normal positions; the immobilisation of the limb, and the dressing of the wounds. The exploration of the fracture can usually be done through the exit wound, which, in consequence of the bone injury, is almost certain to be large enough for this purpose; or, if not, it may be increased. If there be no exit wound, although the chances are that no splinters will require to be extracted or replaced, the entrance wound may have to be increased for the detection and removal of the bullet, if this be impossible without it.

The removal of splinters in these, as in all other cases, should be done with great discrimination: only splinters and fragments which are absolutely devoid of any adherence to the shaft and to the soft parts should be removed. These will seldom be found on the entrance side of the bone; but from the exit in the bone to the exit in the skin, splinters, the removal of which may be necessary, will usually be found scattered about, sometimes three or four inches away from their normal positions. The larger splinters the ends of which are displaced, and all those not

quite detached, should be freed from any soft parts in which they may have become entangled, and pressed back into their normal positions as nearly as possible. The wounds should be well irrigated, drainage provided for the first day or two, and the usual dressings applied.

The limb should be immobilised, with the elbow flexed to a right angle, by any suitable means, and nothing is better for this purpose than Stromeyer's cushion (see fig. 42, page 158). Many authors refer to the dangers induced by anything like tight bandaging in cases of fracture of the humerus. Whatever means are employed, care must be taken that both the shoulder and elbow joints are fixed; and, as the cure of these cases takes from six weeks to two months, these joints will require attention with regard to passive motion and massage, as soon as sufficient consolidation of the fracture has occurred to permit of the employment of these methods. Even with attention to this matter, ankylosis frequently occurs, sometimes in consequence of fissures extending into the joints, and sometimes owing to the long-continued fixation. The shoulder is especially liable to fibrous ankylosis from the latter cause.

Of the cases of fracture seen in a civil hospital, probably none are so likely to become complicated by nonunion and false joint as those of the humerus; but in war hospitals these difficulties are quite exceptional. Only 6 cases are recorded by Otis as having occurred amongst 2,900 cases treated conservatively during the American War, and 2 of these were cases of simple fracture. Some shortening of the humerus almost always results, and its extent depends on the length of loss of substance between the broken ends: there may be none when, although the continuity of the bone is lost, a fragment remains on the entrance side of the fracture, preventing the approximation of the upper and lower fragments to each other.

Wounds of the thorax and its contents are serious complications which may accompany gunshots of the humerus. Their treatment will be considered in another chapter.

Gunshot Fractures of the Forearm.

From 10 per cent. to 15 per cent. of the gunshot fractures met with in war hospitals are fractures of the shafts of the bones of the forearm. During the American War, a little more than one-third of these injuries implicated the radius, about the same proportion the ulna, and somewhat less than one-third were fractures of both bones. In America most of the cases were treated by the conservative method, with a mortality of 6.4 per cent.: the same line of treatment in fractures of the ulna alone gave a mortality of 5.6 per cent., and of the radius 5 per cent., but in the latter cases the functional disabilities after recovery were of a graver nature.

The bones of the forearm are composed of especially hard and brittle tissue, and in consequence of the thinness of their shafts are liable to be fractured cleanly without prolonged fissuring or fragmentation, the immediate site of injury being quite cleared of bone and showing a distinct loss of substance between the broken ends. Even the older rifle-bullets occasionally passed between the bones without fracturing either, but with the modern projectile this may readily happen. Both bones may be fractured by a bullet striking the forearm obliquely or from either side, and the nearer the direction of the bullet is to the antero-posterior line the greater will be the probability of only one bone being broken. When both bones are implicated, the comminution of the bone on the exit side will be of a more severe character than that of the bone first traversed by the projectile, in consequence of the fragments of the latter being propelled outwards, and so causing increased damage to the former.

Hæmorrhage from wounds of the larger vessels, as well as of the two interosseous arteries, is a common complication in gunshots of the forearm, and must be treated by ligature of both ends of the vessel in the wound. There is not much difficulty in this procedure for the radial and ulnar vessels in any part of their course, but ligature of

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the interosseous arteries may be a difficult operation. Nevertheless, this is the procedure to be adopted, in consequence of the very free anastomoses of the vessels of the forearm. The use of the Esmarch tube will be an invaluable help in the ligature of these deeply placed arteries. Diffuse traumatic aneurism is a fairly common occurrence, especially when the interosseous arteries are wounded. Direct ligature of the vessel above and below is the ideal treatment for this condition, but it may be impossible to carry it out. Under the latter circumstances the brachial must be tied; but cases of this kind will often necessitate amputation.

The Treatment of gunshot fractures of the forearm should, in the very large majority of instances, be directed towards the preservation of the limb. Conservative treatment is only contra-indicated in exceptional cases of extreme disorganisation of the forearm, and in those accompanied by laceration of almost all its principal arteries. The comminution of bone is not usually very extensive; but even if it be so, this does not preclude conservation. In America almost all the cases where both bones were fractured, suffered amputation; but since with modern methods of wound treatment we may expect to save a very large majority of forearms, even when both bones are fractured, this condition cannot be admitted as a contra-indication for conservation. The uses of the limb will, no doubt, be much curtailed, but any remnant of a forearm and hand which it is possible to preserve will be of inestimable value to its possessor, and far more so than any artificial substitute which he could obtain.

Conservative Treatment is the method which should always be employed in cases of gunshot fractures of one of the bones of the forearm, even when complicated by wound of the radial or ulnar arteries. Delorme considers that wound of both of these vessels, so long as the interosseous arteries are intact, does not indicate primary amputation in cases of fracture of one bone. Conservation should not be practised when both bones are fractured and the large vessels are also wounded; an implication of the median nerve,

certainly of the median and ulnar nerves, with fracture of both bones, should contra-indicate the conservative method. But, under other circumstances, an attempt to save the limb should be made, and will probably succeed, even when both bones are broken.

The procedures to be carried out are similar to those already more fully detailed in other kinds of cases. Bleeding vessels should be ligatured, severed tendons and nerves, if possible, sutured, quite detached splinters extracted, the wounds and bullet track irrigated, and drainage provided if the wound has had to be explored. The immobilisation apparatus must extend from the finger-tips and include the elbow, which should be flexed to a right angle. Care is required when applying it, to avoid approximation of the ends of the fractured bones to each other by pressure of the bandages. When this is not attended to, attachment of the radius to the ulna is very likely to occur at the site of fracture, with the result of complete loss of the power of pronation and supination (fig. 57). To prevent this accident happening, long, narrow interosseous pads should be used, and splints of sufficient width to prevent contact of the retaining bandages with the arm. Longmore refers to fractures of one bone of the forearm or leg as "resecting fractures," and mentions this complication.

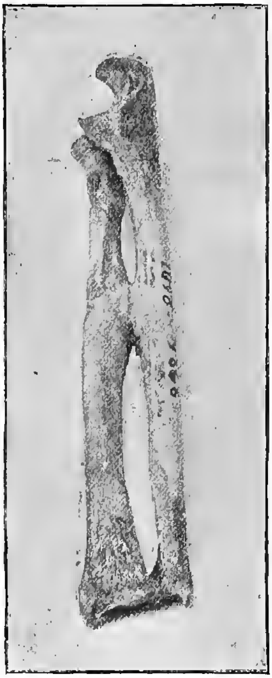


FIG. 57.
Union of radius and ulna in case of gunshot of radius.—*Netley Museum.*

During convalescence from these injuries, the joints of the fingers, the wrist, and the elbow will require early and prolonged attention on the lines already indicated, to avoid the occurrence of partial or complete ankylosis.

Primary Excision in the Continuity of the bones of the forearm for gunshots is not a justifiable operation. The mortality following it is twice that of conservative treatment, and in the American War, when it was extensively used, Otis was unable to record a single case of satisfactory result as regards the utility of the limb.

Beck, writing of gunshots of the forearm in the war of 1870–71, says: "Regarding resection in the continuity, I cannot approve of the operation. Aside from the fact that by such interference osteomyelitis and pyæmia may readily be caused, serious disorders, such as injuries of blood-vessels and subsequent hæmorrhages, may be induced. The two resections performed by us in the radius and ulna were more properly extraction and pinching off of splinters, and partial sawing off of prominent sharp points of bone, a proceeding which under some circumstances may be approved, as thereby, without injury to the wound, serious complications may be averted."

As a **Secondary Operation,** excision may be useful in cases where one bone only has been fractured and union has failed to take place. Here, refreshing the ends of the broken bone, and excision of as much of the sound one as will allow of the approximation of the ends of the former, combined with suture of both bones with wire, may have the desired effect.

Amputation for gunshots of the forearm should be performed when both bones are fractured, and the radial, ulnar, and interosseous arteries are also wounded. These indications for amputation were laid down by Guthrie, and can hardly be improved upon. Delorme further considers that wound of both principal nerve trunks requires similar treatment. The mortality in the American War was 13.9 per cent. for all cases: 9.6 per cent. for the primary, 23.5 per cent. for the intermediary, and 15.9 per cent. for the secondary operations.

GUNSHOT WOUNDS OF THE DIAPHYSIS OF THE FEMUR.

During the American War about 2.5 per cent., and during the Franco-German War about 3.5 per cent. of all gunshot wounds were found to be fractures of the shaft of the femur, and in the same campaigns about 25 per cent. of all the fractures of long bones were of the femur.

Of all the gunshot injuries of the extremities seen in warfare, the gravity of gunshot fractures of the femur ranks second only to that of similar injuries to the hip joint. The difficulties of treatment, and the death-rates following all modes of treatment, increase as the site of the wound approaches the great trochanter. The ratios of mortality in 6576 cases of gunshot fractures of the shaft of the femur recorded during the American War, were for the upper third 49.7 per cent., midle third 46.1 per cent., and lower third 42.8 per cent.; and these figures fairly represent the proportions which obtained in the results observed in other campaigns.

No long bone in the body offers as much resistance to the passage of a bullet as the femur, and, as a consequence, the number of the fragments and the length of the splinters found in fractures of this bone, produced by projectiles at high velocity, are proportionally great.

Mere contusions of the bone accompanying wounds of the soft parts covering it are injuries of a nature likely to produce complications of a grave and even fatal character. These have already been alluded to. The watchful care required for their early recognition, and the very active treatment necessitated by their serious results if neglected or improperly dealt with, have also been pointed out. Simple contusions of the shaft are detailed by Otis in 162 cases, with a death-rate of 22.8 per cent.; 9 of these required secondary amputation of the thigh, and 2 died. Otis believed that many cases which were supposed to be mere flesh wounds were really unrecognised cases of this class. The death-rate given is, therefore, probably too high. During the French Campaign in Tonquin, only 2

are stated to have completely recovered out of 10 cases treated.[1]

As already stated, when speaking of contusions of long bones generally, all the serious consequences possible to arise in these injuries of the femur depend on, and are the direct and certain results of, the occurrence of suppuration in the wounds and in the bullet tracks. In the absence of this condition all these cases should recover without giving rise to difficulty or anxiety, and the means to be employed to avoid it are simple and easy of fulfilment. If the skin wound, and the track leading to the contused bone, are rendered aseptic by means of irrigation, and kept so by the application of sterile gauze and wool dressings, wounds of this class should heal almost by first intention. The bullet will be found lodged in the great majority of these cases, except where the bone contusion has been caused by a graze. Under these circumstances it should be removed if possible; but if this cannot be done immediately, the treatment should otherwise be the same. The bullet may become encysted, and cause no further inconvenience; or it may be removed later in the course of the case when all danger of bone complication has passed away.

Gunshot fractures of the femur may be of all degrees of severity, from those simple cases of transverse fracture, absolutely without comminution, often produced at a little distance above or below the point of impact of a grazing bullet, to fractures accompanied by the most severe comminution and extensive fissuring, sometimes implicating even both joints. An instance of the former kind of injury is shown at fig. 12 (p. 52), taken from a photograph of a specimen sent to the Museum of the Army Medical School by Brigade-Surgeon-Lieutenant-Colonel H. W. A. Mackinnon, D.S.O. The bullet was accidentally discharged from a Lee-Metford rifle, and wounded a man at 70 feet distance, passing through both thighs. It barely grazed the linea aspera of the femur first traversed, and then severed the femoral vessels of the second thigh, the man dying of hæmorrhage almost immediately. A scale of bone, no

[1] Chauvel and Nimier.

thicker than a sheet of paper, was removed from the femur by the glancing contact, and the transverse fracture was produced about an inch higher up.[1]

Bullets travelling at very low rates of velocity may produce clean-cut perforations on the entrance side of the femur with some thread-like fissures, but without comminution or complete loss of continuity, while on the exit side the bony wall may be driven outwards with some slight fragmentation. A bullet travelling at the highest rates of velocity produces, besides the extensive comminution and fissuring already alluded to, complete loss of substance for considerable distances between the ends of the fractured bone, the immediate site of the injury being quite cleared of splinters and bone débris. Any of the large vessels and nerves of the thigh may be wounded by the direct contact of the projectile; but injury to these important structures is more likely to be produced, in a secondary manner, by the passage of a bullet from the outer to the inner side of the thigh, than when it travels in the opposite direction, in consequence of the much greater extent of the destruction effected on the exit side by the bone fragments which are driven outwards.

The general position of the large vessels of the thigh is on the inner side of the limb, and when the exit wound of the bullet is also on its inner aspect the probabilities of their being wounded are greater than when the bullet makes its exit through the less important structures on the outer side. The statement, indeed, applies in all gunshot fractures of long bones, that an exit through important anatomical structures, other things being equal, causes a more dangerous injury than does an entrance wound through similar parts. The large vessels of a limb, in a gunshot fracture cases, are far more likely to be lacerated by splinters of bone driven outwards by the bullet, than they are to be wounded by the bullet itself. The vessels of both upper and lower limbs lie to their inner surfaces; and therefore all cases in which the exit wound is on the inner side are more liable to be complicated by severe

[1] Van Coler reports precisely similar cases in his experiments.

hæmorrhage, and are, generally, more dangerous injuries.

The Treatment of gunshot fractures of the femur needs to be considered only under two heads — conservation and amputation. Excision in the continuity of the shaft has been practised, notably during the American War, but the operation is now known to be no more justifiable in the case of the femur than it is in that of the humerus. Otis records 175 cases so treated, with a death-rate of 69.4 per cent., a mortality which has only been exceeded by amputation in the upper third, almost the most fatal operation in military surgery. The death-rates following excision and amputation are shown together for comparison in the following table:—

	Excision.	Amputation.
Upper third	66.2 per cent.	73.3 per cent.
Middle " .	68.9 "	55.3 "
Lower " .	68.7 "	45.0 "
Site undefined . .	84.2 "	80.7 "

Secondary amputation was subsequently required in 6 cases, and disarticulation at the hip in 1 case. The opinions of American and European surgeons are fairly represented by those of Otis, Hamilton, Gross, Ashhurst, MacCormac, Schwartz, and Demme, and are to the effect that resection in the continuity of the femur for gunshots is a bad operation, and should not be repeated.

Conservative Treatment.—Until about the year 1850, almost all military surgeons of note recommended primary amputation in all comminuted gunshot fractures of the femur. This was the old rule laid down by Guthrie, Larrey, Baudens, &c., and was held to have the force of a law. Now Chauval and Nimier point out that the experiences of the later campaigns, in Schleswig-Holstein, the Crimea, Italy, America, and in the Franco-German War, "have established the superiority of conservation over amputation," and that "the prognosis of conservative treatment has improved from war to war."

The indications for the conservative treatment of these cases embrace injuries of almost the greatest severity as

regards comminution of bone; the number of the fragments, the extent to which they are displaced, and the amount of fissuring—even though the latter condition may be suspected of implicating the hip or knee joints—cannot be taken as data on which to decide against conservation. The surgeon must look rather to laceration of the main vessels and nerves of the thigh in cases of comminuted fracture of the femur, and extensive destruction of other soft parts, before he can determine that the probabilities are against recovery under treatment by this method. The death-rates following amputation in any part of the thigh, during the first day or two after operation, which are hardly decreased by modern methods of wound treatment, are so high, that almost anything which avoids its employment is preferable; whereas, with an aseptic condition of the wound, almost anything is possible with conservative treatment.

From the first extreme, that all cases required amputation, the pendulum is now swinging towards the other, that no case should be so treated; and, with absence of infection of the wound, the latter view may almost be considered the correct one. But when the injury is produced by large projectiles or by large fragments of shell, in which case the laceration and destruction of the soft parts of the limb are certain to be extreme, and the main vessels and nerves are probably wounded, conservative treatment is contra-indicated. In all other cases, in all those produced by small-arm projectiles, and unaccompanied by wounds of the femoral artery and of the great sciatic nerve, conservation should be undertaken.

Even before antiseptic methods were used in these cases, and the rule for amputation laid down by the older authorities notwithstanding, it was beginning to be apparent that fewer patients were lost when conservation was attempted in the most severely comminuted gunshot fractures of the femur than when amputations were performed. Now, with the practical certainty of the wounds running an aseptic course, the saving of lives and the preservation of fairly useful limbs will come so prominently forward that ampu-

tation must be restricted to those cases which are hopeless without it, and patients will not, as formerly, be subjected to operations with high rates of mortality, while the safer method was only employed in the simplest cases.

The Procedures to be carried out when conservative treatment has been decided on are, in the main, those already referred to under similar circumstances. The utmost care must be taken with the treatment of the wounds and surrounding skin to render them aseptic, and the condition of the fracture must be explored with the finger. Splinters which are quite detached from their connections with the bone and with the soft parts are to be removed through the exit wound, and those which are still adherent, but displaced, readjusted as nearly as possible in their normal positions. All bleeding vessels should be ligatured, the wound thoroughly irrigated with a weak antiseptic solution, drainage provided for the first day or two, and the usual dressings applied.

Absolute immobility, by means of a fixed apparatus, is necessary in all cases of gunshot fracture of the femur. The apparatus employed for this purpose must include the pelvis and hip, and extend to the foot. Splints of zinc or of wire-netting, re-enforced, where possible, by strips of Gooch splinting, are the best to use at first. Later, when the wounds are healed, or nearly so, and windows are sufficient for applying the dressings, plaster bandages, strengthened by thin strips of wood or iron-hooping or by Gooch splints, will be the more satisfactory means of immobilisation. When displacement forwards of the lower end of the upper fragment, or backwards of the upper end of the lower fragment occurs, an apparatus on the plan of the double-inclined plane will be found most useful for the reduction of the deformity (figs. 58, 59, and 60). Extension and counter-extension by the usual means is required, except when the loss of substance between the broken ends of the bone is distinct and well marked: in these cases, if the ends of the bones are kept far apart by weights, union cannot take place satisfactorily.

The final results in these cases treated conservative-

ly are distinctly good. The loosened splinters become included in the callus thrown out, and eventually firm consolidation takes place; but from two to six months may

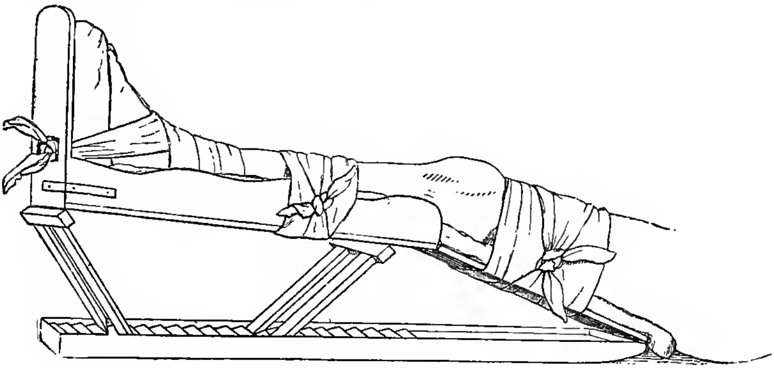


FIG. 58.

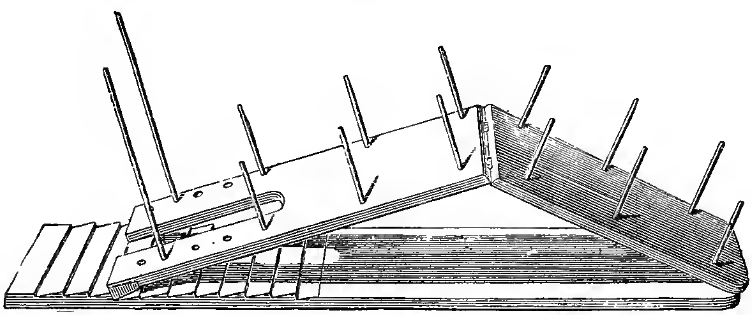
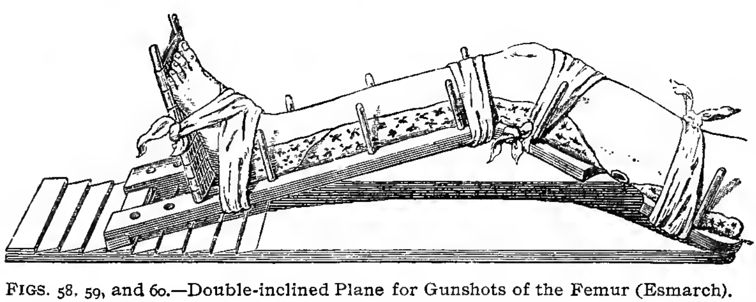


FIG. 59.



FIGS. 58, 59, and 60.—Double-inclined Plane for Gunshots of the Femur (Esmarch).

elapse before recovery is far enough advanced to enable the patient to get about with crutches, and perhaps twice

as long before recovery is complete. The usual deformity which is found, when any occurs in these cases, is a convexity of the femur outwards (fig. 61). Shortening of the femur almost always occurs; it is usually well marked, and sometimes may extend to many inches. Ankylosis, either partial or complete, of the knee or hip is also a common result, depending on implication of the articular surfaces in the fracture, or on the long-continued confinement of the limb in fixation apparatus.

FIG. 61.

Showing usual deformity in badly united gunshots of femur (after Otis).

The mortality following conservation during the American War was 49.9 per cent., while that of *all the primary* amputations was 49.8 per cent. The mortality of conservative treatment according to the site of fracture was—

Upper third	.	46.0 per cent.
Middle "	.	40.6 "
Lower "	.	38.2 "

all of which ratios are less than those furnished by amputation at the same situations. Again, the total mortality of 49.9 per cent. for conservation may be compared with that of *all* amputations of the thigh for gunshot of the femur itself, which was 53.8 per cent.

Amputation for Gunshots of the Femur.—Some of the indications for this operation have been referred to under conservative treatment. It is required when the limb has been wholly or partially torn away by a large projectile or by a large fragment of shell; in severely comminuted fractures with extensive destruction of the soft parts, denuding the bone of its coverings for a considerable distance—usually the results of shell wounds; and in comminuted fractures complicated by laceration of the femoral vessels, or of the great sciatic nerve in the higher parts of its course.

But cases in which the large vessels of the thigh are wounded will seldom live to come under treatment. Otis could place on record only two cases of recovery, without amputation, where the femoral artery was wounded. Delorme is of opinion that partial or complete section of the sciatic nerve does not necessitate primary amputation, but he suggests that removal of the limb will be required at a secondary period.

A case was in the Royal Victoria Hospital, Netley, in 1892, which is of interest in this connection. Lance-Corporal M. was invalided from India on account of a gunshot of the soft parts of the thigh, a little below the level of the tuber ischii, lacerating the sciatic nerve; the wound had healed in about three months. On arrival at Netley the leg was almost useless; the muscles were greatly wasted, the power of flexion in the knee was almost lost, and power of voluntary movement of the foot and ankle was quite absent. There were scars of healed ulcers in many places on the limb, and some were still open; there was complete loss of sensation on the posterior aspect of the leg and thigh. Trophic changes were very evident; the skin was pigmented in patches, it was congested, and the ulcers just referred to were also trophic lesions. The man could walk, but only with great difficulty, and the foot and ankle soon became œdematous. No knee reflex could be obtained on the affected side, and the muscles gave no response to the interrupted current. An exploratory operation was undertaken with a view to suture of the nerve or to engraft a piece of dog's nerve. A very deep dissection was made, and the upper end of the nerve found, firmly bound down against the femur; it was bulbous, and about the size of a walnut. No trace, however, of the lower end could be found after very free dissection, and, as it was certain that there was a loss of substance of at least four inches between the ends, the operation was abandoned as impracticable. In this case the bone was uninjured, and conservative treatment was therefore the method to be pursued; but had it been complicated by a severely comminuted fracture of the femur, amputation would have been the better treatment,

relieving the patient of a useless limb, which was the cause of intense pain, and subject to ulcerations from trophic lesions of the skin.

The death-rates following the amputations performed during the American War for gunshots *of the femur* itself, differed from those following amputations through the femur for gunshots of the knee, leg, and ankle, as the following table will show:—

	For Fracture of the Femur.	For Fracture of the Knee, Leg, and Ankle.
Upper third . .	73.3 per cent.	53.8 per cent.
Middle " .	55.3 "	44.5 "
Lower " . .	45.0 "	53.6 "

Defining more particularly the site of injury in the last group, the mortality of amputations through the femur for wound of the knee was 51.1 per cent., for wound of the leg 56.1 per cent., and for wound of the foot and ankle 54.6 per cent. "Thus it would seem," Otis remarks, "that of all the amputations in the thigh performed for shot fractures, those done for fractures of the lower third of the femur offered the best chance of life." As regards the period when the operation was performed, the mortality of all the primary amputations was 49.8 per cent., intermediary 63.7 per cent., and secondary 45.9 per cent. It will be observed that the primary operation in the thigh gave a higher mortality than the secondary, while in the arm the primary operations gave a lower rate than the secondary by 9.3 per cent.

In cases where the thigh is completely torn away by a large shell fragment, Delorme considers that a new amputation should only be performed when the injury is in the lower third, and when the traumatic shock is but slightly marked. Other cases should have the soft parts trimmed, or be treated by the method of "simple expectancy" rather than by amputation, in consequence of the profound shock which accompanies them, and of the danger of further loss of blood entailed by operative interference. Certainly no operation should be performed while constitutional shock is present; but to leave a case of this kind to the unaided

efforts of nature, must inevitably result in a conical stump, with protrusion of the end of the bone and retraction of the muscles. The stump left by the projectile in these cases is usually flat, the bone and muscles being severed at the same level, and some fashioning of it, in order to bring it to at least a semblance of what is left by a systematic amputation, is absolutely necessary. Operation need entail hardly any further hæmorrhage, for enough of the thigh is always left for the efficient use of an Esmarch's tube. If the patient when first seen is not in a condition to undergo the necessary procedure, the skin and the lacerated soft parts should be disinfected, and well covered with gauze wrung out of 1–40 carbolic solution, after the vessels on the face of the stump have been ligatured. Treatment should then be directed to remedy the effects of the severe shock, and when this has proved successful, as much of the femur as may be considered necessary should be removed through a longitudinal incision on the outer side of the thigh, and the soft parts adapted to cover the bone in the way which may seem most suitable to the particular case.

In determining the line of treatment to be adopted for injuries of the lower extremity, and especially for gunshot fractures, whether it shall be conservation or amputation, the decision must be allowed to depend to a large extent on the existence or otherwise of a necessity for moving the patient. In the particular cases under consideration, those of fracture of the femur, if the military requirements of the campaign make it imperative that seriously wounded men must be immediately moved towards the base of operations, amputations will have to be done in a large number of cases in which, under other circumstances, every hope of satisfactory result might have been entertained from conservative treatment. If the operation can be performed in either the lower or middle third, amputation will certainly offer the better chance of life; but in the upper third, both the amputation and the fracture are so fatal in their results that it may be advisable not to interfere. Then, again, the kind of transport available for these cases must be taken into consideration. If it be by boat or rail-

way, possibly enforced removal of the wounded may not be believed to entail amputations in cases not requiring the operation from a purely surgical point of view.

The methods of operation to be employed must, of course, be varied according to the extent and situation of the injury to the soft parts; but it may be laid down as a general rule that the antero-posterior flap operation is suitable to all parts of the thigh; while in the lower third, and in fleshy limbs, the circular or modified circular operation gives excellent results. In consequence of the extent and irregularity of the retraction of the muscles which occurs in the thigh, conical stump is peculiarly liable to result from any amputation in this situation. For this reason, and because the patients treated in military practice in the field are men who have lately been in vigorous health and activity, whose muscles are all the more likely to unusual retraction, special attention must be paid to providing ample covering for the stump.

Gunshot Fractures of the Leg.

Gunshot fractures of the bones of the leg are found to comprise about a third of all the fractures of long bones met with in war hospitals from projectiles, while about 3 per cent. of *all* wounds are found to be in this region. Both bones of the leg are peculiarly hard and resistant: the tibia, of all long bones, ranks second only to the femur in strength, while the fibula is the most compact and brittle long bone in the body. The tibia is therefore liable to sustain fractures in which the comminution and fissuring are very extensive, numerous large and small fragments and splinters being produced; while the fragments of the fibula, in consequence of the thinness and brittleness of the shaft of this bone, are usually small, and the fissuring, if any, very slight. The diaphysis of the latter bone, also, is especially apt to suffer loss of substance at the site of fracture from bullets at a fair velocity. This may also happen in the diaphysis of the tibia from bullets at a high velocity; but the usual kind of fracture observed in this

case is a perforation of the wall of the bone on the near side, with fissures extending for several inches up and down the shaft, and slight loss of substance in the wall of the bone on the far side, with fragmentation into large and small pieces (figs. 62 and 63).

One or both bones may be fractured at the same time, or the bullet may pass between them without touching

FIG. 62.

Fracture of tibia by Lee-Metford bullet at fifty yards' range; entrance side.—*Netley Museum.*

FIG. 63.

Exit side in case shown in Fig. 62.—*Netley Museum.*

either. The bones may be grooved by a missile, or a perforation without solution of continuity may be made at very long ranges; but this is more liable to occur in the tibia, and especially in or near either epiphysis. Simple contusions may result from bullets striking tangentially, or when travelling at low velocities. Hæmorrhage is a very common complication of these cases, and tetanus would appear

to be especially apt to occur in them, 20 per cent. of all the cases of this very fatal complaint seen during the American War having followed gunshots of the lower extremity.

The Treatment of gunshot fractures of the diaphyses of the leg bones should, in the great majority of cases, be carried out on the conservative plan. Simple contusions of either bone should, of course, be treated by this method. Comminuted fractures of one or both bones, almost irrespective of the extent of fragmentation and fissuring, should be treated conservatively when the tibial vessels or the posterior tibial nerve are not wounded, and when the soft parts are not so disorganised by a large projectile or shell fragment as to leave no alternative but amputation.

Beck was at one time an opponent of the conservative method except in comparatively slight cases, and recommended amputation in all gunshot fractures of both bones; but after his experience in the Franco-German War he admits that "there is a large and fruitful field opened to the expectant conservative treatment of gunshot fractures of this limb," in consequence of the ease with which injuries in the superficially placed bones can be recognised and treated, and because there is no difficulty in the removal of loose splinters and pieces of dead bone. Sédillot considered that "primary amputation is indicated when both bones are fractured close to the knee, with or without the complication of hæmorrhage, which adds to the necessity of the operation." Legouest says that amputations are indispensable when both bones of the leg are extensively fractured, and when the tibia alone is fractured with much splintering and loss of bone substance. Hamilton[1] says that "gunshot fractures of the shafts of both tibia and fibula demand amputation where comminution is extensive, or the pulsation of the posterior tibial artery is lost, or the foot is cold and insensible.

With regard to laceration of the vessels and nerves of the leg, it is hardly possible that the tibial arteries should be wounded by a bullet, or by a fragment of bone, without

[1] "Treatise on Fractures and Dislocations," Philadelphia, 1875.

wound of their respective nerves also taking place, so close are the relations of the two nerves to the two arteries in their course down the leg. If, therefore, conservative treatment be attempted under these circumstances, gangrene is very likely to occur and render amputation necessary at a later date; or, if it be successful so far as to preserve the leg, the latter will be only a useless and often an extremely painful encumbrance to the patient, from loss of nerve function, or from implication of the nerve trunk in the callus thrown out. Wound of the posterior tibial vessel is a more serious accident than that of the anterior, because it is almost certain to be accompanied by destruction of the main nerve supply of the foot. Finally, fissuring into the knee or ankle from a fracture in the vicinity of the joints is no contra-indication to conservative treatment.

Conservative Treatment.—The cases treated conservatively during the American War gave a mortality of 13.8 per cent., which, high though it be for injuries of this class, is far lower than that of any operative interference resorted to in the same war. In a large number of the cases the final results were bad as regards the functional utility of the limbs, the patients suffering from persistent caries and necrosis, projection of the fractured ends, outward or inward curvatures of the shafts of the bones, ankylosis of the knee or ankle, atrophy of the muscles, and inability of the limb to support the weight of the body, all of which unfortunate conditions were due to the effects of suppuration in the wounds. With septic wounds the wonder is that the mortality was not higher. With aseptic conditions the death-rates will be decreased, while the occurrence of the disabilities above-mentioned may be expected to be altogether prevented.

The gravity of simple contusions of the diaphyses of long bones has been already insisted on, and the treatment indicated. Asepticity in the wounds, and immobilisation of the limb until all danger of inflammatory bone mischief has passed, are the points to be attended to. In the American War 183 cases were treated, with a death-rate of 9.09

per cent., amputations in the leg being required in 8 of them, with 4 deaths.

The conservative treatment of gunshots of the bones of the leg is to be proceeded with on the same principles as those employed for the same method or fractures in other situations. The tibia and fibula are placed so superficially that the extent of the comminution can be ascertained by external examination. Exploration with the finger is therefore not called for except where the necessity for the removal of loose splinters is suspected. The utmost accuracy of procedure to ensure asepticity should be carefully attended to; hæmorrhage should be controlled by ligature of both ends of the vessels in the wound, and when either of the tibial arteries is wounded, the condition of the corresponding tibial nerve should be looked to with a view to possible suture; quite detached splinters lying in the wound should be removed, and others replaced as far as possible; drainage should be provided; the wounds dressed in the usual manner, and the limb immobilised and slung. For the purpose of immobilisation, hollow zinc-sheet splints, the double inclined plane (see fig. 58, page 251), MacIntyre's splint, or the box splint (fig. 54, page 224) already referred to, are very suitable; but any apparatus in which the bones can be kept in position, and which permits of access to the wounds, will be satisfactory. If the fracture be close to the knee joint, the latter should be included in the fixation arrangement, and if the limb can be slung, the patient will suffer less discomfort. Extension and counter-extension are hardly ever required in these cases.

Excision in the continuity of the bones of the leg has proved as disastrous an operation as it has in fractures of other long bones: the mortality is higher than that following any other method, and the results are infinitely worse than those obtained by conservation. In the American War, excisions of the tibia gave a death-rate of 25.6 per cent., of the fibula 27.2 per cent., and of both bones 61.1 per cent.; while the death-rates following conservative treatment were 10.3 per cent. for fractures of the tibia, 9.7

per cent. for those of the fibula, and 20.2 per cent. for those of both bones. Even if the final results of excision were much better than those of conservation, such high death-rates would render the operation unjustifiable; but the contrary is the fact—both the mortality following it is greater, and the functional utility of the limb is less. Delorme points out the advantages to be gained in cases of fracture of the tibia, with loss of substance at the site of injury, by resection of the fibula. Consolidation of the fracture, under these circumstances, is impossible, because the ends of the broken bone are kept apart by the fibula, and resection of a sufficiency of the latter bone obviates this difficulty. The resected ends of the bones should be sutured with wire. Finally, Stromeyer remarks: "The hopes built on excision in the continuity were found delusive, as well in regard to preservation of life as in regard to usefulness of the limbs preserved by excision;" and Demme says "that I must joint Stromeyer and the majority of military surgeons in condemning the operation."

Amputation of the leg for gunshots of the diaphyses is required, as a primary operation, in severely comminuted fractures accompanied by extreme destruction of the soft parts, injuries which are only likely to be produced by large projectiles or shell fragments; in comminuted fractures complicated by laceration of both tibial arteries, or (according to Delorme, Lidell, &c.) with wound of the posterior tibial nerve; and when a part of the limb has been carried away, or nearly separated, by a large projectile. Gunshot fracture of both bones of the leg was formerly considered to be an indication for immediate amputation; but, with strict antiseptic treatment of the wounds, such an injury is no longer held to necessitate operation.

Secondary Amputation is indicated in these cases when conservation fails, and consolidation does not take place in consequence of infection of the wound; for secondary hæmorrhage which is not amenable to other means; to remove the source of infection in cases of aseptic surgical disease; and for acute septic osteomyelitis.

As regards the particular amputation to be performed

in the leg, a good deal must depend on the amount of injury to the soft parts. No "point of election" can be considered in deciding the situation of the amputation, but only as little of the limb as possible should be removed. The different flap operations are usually performed, but the modified circular is most suitable in very muscular limbs. Teale's operation gives an excellent stump, but it entails a high section of the bones, and is tedious in performance. For the latter reason, especially, it is unsuitable for employment during the press of work in a crowded field hospital.

When amputation is required for septic osteomyelitis supervening on gunshot fracture in the leg, it should be performed through the knee joint or in the lower third of the femur. The following table of death-rates for these injuries during the American War is given for easy comparison:—

	Amputation, all Cases.	Primary.	Inter-mediary.	Secondary.	Conser-vation.	Exci-sion.
Upper third .	27.0%	24.4%	34.4%	27.8%	..	..
Middle third	20.6%	16.9%	29.8%	19.7%	13.8%	31.8%
Lower third .	27.6%	24.1	35.8%	28.9%	..	..

It will be observed that these statistics point to a smaller danger to life from amputations in the middle third of the leg than from those performed in the upper or lower thirds, and Delorme remarks upon this that "it is not possible to admit nowadays, as formerly, that amputation as practised in the upper and lower thirds of the leg are more fatal than those done in the middle third. The prognosis for these operations will vary, as for all amputations, according to the condition of the wounded man, the severity of the original injury, and the care which is observed to assure asepsis in the wound." And it may be added that the prognosis should be good, and the mortality will be small for amputations of the leg, irrespective of the situation in which they are performed, in proportion as success is secured in the antiseptic treatment of the site of fracture.

What has been already said regarding the effect en-

forced transport of the patients will have in cases of gunshot fractures of the femur, in necessitating amputation of limbs not otherwise requiring operation, applied with equal force in gunshots of the leg. If the patients must be moved immediately, legs will have to be sacrificed which, under other circumstances, might be saved if treated conservatively.

CHAPTER IX

WOUNDS OF THE HEAD

THE frequency of wounds of the head, or rather the ratio this class of injury bears to the number of wounds of other portions of the body in a particular campaign, depends to a considerable extent on the kind of operations in which the troops may be engaged. In siege operations, in fighting in entrenched positions, and even in engagements in the open where "good cover" is available, wounds and injuries of the head will necessarily bear a higher ratio to those of other parts than would be the case under other circumstances. In the Crimean War, on both the French and English sides, where much of the fighting was done from behind entrenchments, about 20 per cent. of all the gunshots treated were of the head and neck. This is a higher ratio than has occurred in any war during the last sixty years. About 12 per cent. of all gunshot wounds would probably represent the average ratio of wounds of the head in most campaigns.

Wounds of the head, and especially those produced by projectiles of any kind, are a very fatal class of injury. Guthrie, writing on this subject in his "Commentaries," remarks: "Injuries of the head affecting the brain are difficult of distinction, doubtful in their character, treacherous in their cour e, and for the most part fatal in their results;" and this estimate applies to them now, when compared with other wounds, as well as it did in Guthrie's time. If we consider for a moment the intense energy with which bullets impinge upon the skull, and the concentration of that force upon a small area, it will be apparent that gunshot injuries of the head must be accompanied by great destruction of important parts, and that projectiles cause fractures of the skull unlike most of those met

with in civil practice. The concentration of the enormous force on a small area always causes fractures of this kind to be of great severity, and the splintering of the inner table to be of wide extent.

A detailed description of the injuries to the skull and brain produced by bullets, and more especially by the modern bullet, has already been given in Chapter II. It is therefore unnecessary to allude to them again here, except to remind the reader that at fairly short ranges the fracture consists in complete shattering of the calvarium, vault, sides, and base, with separation of the sutures (figs. 64, A and B); while the degree of shattering gradually lessens as the range increases, until at about 1100 yards the fissures have become radial around the exit and entrance holes, and at about 1800 yards fissures may be absent, and clean punched-out holes only be found. But this is not always so at this or at even much longer ranges, for at ranges of a little over 2000 yards considerable fissuring has occurred, especially between the entrance and exit holes. Variations in the degrees of fracture at similar ranges appear to depend on the differences in the thickness and compactness of the various portions of the skull perforated by the bullet. At short ranges the brain is pulped, not only in the immediate neighbourhood of the bullet track, but throughout its whole substance; but injury to the brain so rapidly decreases with increase of range that clean-cut channels through the brain tissue are found at ranges under 150 yards.

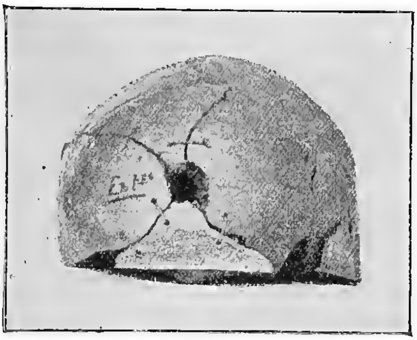


FIG. 64A.

Gunshot of skull at eight yards' range by Lee-Metford bullet.—*Netley Museum.*

Wounds of the Head by Side-Arms.—Sword wounds of the scalp hardly differ at all from the scalp wounds seen in

civil hospitals, either in their characters or treatment. Occasionally they are very extensive, large portions of the scalp being raised from the pericranium and turned downwards. In the treatment of these injuries the head should be shaved over a large area about the wound, and very accurate disinfection of the skin and of the wound secured by the use of one of the weaker antiseptic solutions, all dust and dirt being carefully removed; bleeding vessels should be tied with thin silk or catgut if necessary, the scalp brought accurately together by wire or silkworm gut sutures, and dry gauze and wool dressings applied by means of a double-headed roller which exerts a sufficient pressure to keep the scalp evenly in contact with the pericranium. With an aseptic condition of the wound, healing should take place by first intention; no drain is required.

FIG. 64B.
Gunshot of skull, inner surface, eight yards' range.—*Netley Museum.*

Sword and Bayonet Fractures of the Skull.—The statistics of the American War bear out the observation of Hennen that sword cuts on the top of the head are not such fatal injuries as are those on the sides. Boyer, a French surgeon, had already drawn attention to this fact, and Guthrie points out in his "Commentaries" the danger of wounds of the anterior lobes of the brain. He says: "An injury of apparently equal extent is more dangerous on the forehead than on the side or middle of the head, and less so on the top or back of the head than on the side."

It sometimes happens that a sword cut on the head

slices away a plate of bone which remains adherent to the scalp. The treatment to be pursued in these cases, with regard to the bone fragment, has been a subject of difference of opinion amongst surgeons. Should the bone be removed from the scalp and the latter only replaced? or should the flap and bone be replaced together? Dupuytren, Legouest, and others adopted the former plan, fearing necrosis and suppuration from leaving the piece of bone to act as a foreign body; while Paré, Guthrie, and many others recommended the latter method, leaving the bone undisturbed. Guthrie writes: "When a portion of bone is sliced off with the scalp, and adheres firmly, the scalp and bone should be reapplied; when the fragment of bone has but little adherence, it should be removed." In the present day there is no doubt as to which method should be employed. The plates of bone removed by the trephine are now replaced by most surgeons, with good results, although they retain no adherence whatever to the scalp; how much more reasonable, therefore, is it that we should endeavour to get plates of bone detached by sword cuts, but still adherent to the scalp, reunited in their normal positions; and, if the wounds remain aseptic, success in these attempts is certain.

Incised Fractures of the Skull.—Sword fractures of the bones of the cranium are not very numerous in warfare. Otis only records forty-nine such injuries amongst the enormous number of wounds treated during the American War. When the weapon strikes perpendicularly, it makes a clean cut in the bone with even edges, and perhaps one or two fissures extending a short distance from the ends of the incision when the whole thickness of the bone is implicated. Whether one table only or both tables are fractured, and whether the brain be wounded, and, if so, to what extent, naturally depend on the force with which the blow is delivered and on the depth to which the sword penetrates. If the weapon strikes obliquely, a round or oval piece of bone may be sliced off; or, if not quite detached, it may be found loose from fracture of what might be called its pedicle being produced by the wedge-like ac-

tion of the blade between the lips of the incision (figs. 65 and 66). In this case also one or both tables may be involved, and more or less extensive portions of the brain substance may be included.

When both tables are fractured, the injury to the inner one is always more extensive than that of the outer, and the edges of the incision in the former are forced inwards towards the brain. With even the merest dent in the outer table, the inner table may be severely fractured and displaced. This is due not to the greater brittleness of the latter, as was formerly supposed, but to the want of support it suffers as compared to the former during the occurrence of the injury. When a fracture of the bones of the skull is produced from within outwards, the conditions are reversed, and the outer table, the one then receiving the lesser support, is found to experience the greater damage.

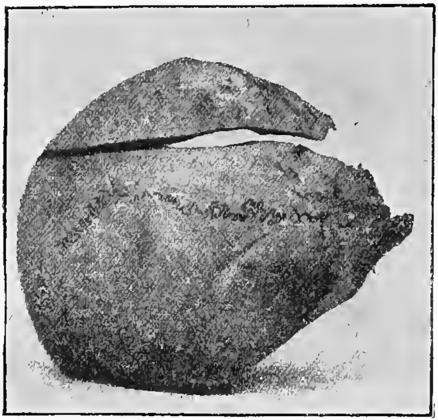


FIG. 65.

Sword-cut of the skull, produced by Afghan sword.—*Netley Museum.*

Fractures of the inner table without fracture of the outer may result from contusions or from sword cuts of the skull. This was also supposed to be due to the greater brittleness of the former; but Mr. Teevan[1] has suggested a more probable explanation, *i.e.* that fracture in any substance always commences, in response to force applied, on the surface of extension, not on that of compression. He points out, for instance, that if a force be applied to a stick so as to bend it, the fracture will begin on the outer side of the curve, the extension side, not on the inner or compression side. When a body of convex form has a

[1] *British and Foreign Medico-Chirurgical Review*, October 1865.

force applied to it, the tendency is towards a lessening of its convexity by bringing it nearer to a plane surface. Hence in the case of the skull the inner table will be on the extenson side, and may be fractured while the outer remains whole. This has been proved experimentally. For, when the force is applied to the inner table, the outer one may be fractured without fracture of the inner, the former in this case being on the extension side.

The Treatment of incised fractures of the bones of the skull, as of all injuries in this situation, requires to be car-

FIG. 66.

Sword-cut of skull, by Afghan sword.—*Netley Museum.*

ried out with special and particular regard to an aseptic condition. Suppurative inflammation of the brain and of its meninges is the common cause of death in head injuries, and is the certain result of infection of the wound. Asepsis is the only means of preventing this complication. In all cases of wounds of the head, the scalp should be shaved over a large area, and the skin thoroughly disinfected. The wound and the fracture should then be asepticised, and the latter gently explored with a probe if any doubt exist as to fracture of the inner table. If fracture of the inner table has not occurred, the wound should be closed by sutures, and dressed in the usual manner. If, however, both tables are found to be injured, the certainty of the greater damage to the inner table, and the great probability of fragments of the latter having been driven

inwards, so that their sharp and jagged points lacerate the dura mater or brain substance, will force into consideration the questions of the elevation or removal of the depressed fragments. If a diagnosis of depression of fragments of the innner table be made, it is necessary that they be elevated or removed at once by means of the trephine, if other methods do not succeed, and without waiting for symptoms of irritation of the brain or its membranes to arise. If the diagnosis of depression of fragments of the inner table be doubtful, we must still remember the probability that they are depressed, and the certain dangers of consecutive brain mischief from this condition which can only be obviated by operation. I should therefore operate in all cases of incised fractures of the skull implicating both tables.

Trephining adds nothing to the immediate or remote dangers of the case, if performed with proper precautions to ensure an aseptic course; and if we delay until symptoms show themselves, it may be too late for the operation to have the desired effect. The question of the use of the trephine in fractures of the skull will be more fully entered into later on in connection with gunshot fractures.

Punctured Fractures of the skull, the results of sword or bayonet thrusts or of other similar weapons, are particularly dangerous injuries. The fracture of the outer table may be nothing more than a clean-pierced hole, with or without, but probably with, some extent of fissuring; but the fracture of the inner table is certain to be depressed over a comparatively large area, and to present triangular fragments of bone, the sharp corners of which are driven into the dura mater and brain. In these cases secondary inflammation of the brain and meningitis are certain to supervene, unless the cause liable to produce them be removed. Immediate operation with the trephine under these circumstances is imperative. The other details of treatment should be carried out on the lines just laid down.

All patients suffering from incised or punctured fractures of the skull should be treated, as far as possible, with

absolute rest and quiet, and placed on low diet; a saline or calomel purge should be given, or croton oil if they are unconscious. After apparent recovery from injuries of these kinds, men are liable to suffer from various disabilities depending on brain lesion, which will be referred to at the end of this chapter.

Gunshot Injuries and Fractures of the Skull.—The marked peculiarity of gunshot wounds of the head is, in many cases, the small amounts of visible injury compared with the real extent of damage which may have occurred within. Cases of mere contusion of the bones of the skull, with or without penetration of the scalp, but uncomplicated by fracture, are not likely to be produced by small-bore bullets. With the old spherical bullet they were comparatively common, and they may occasionally result even from the modern projectile at long ranges. In the American War 328 cases were treated, and Otis remarks that they "were very frequently followed by grave symptoms, such as those of hæmorrhage within the skull, periostitis, caries, exfoliation of bone, and, possibly, the remote effects of a condition of chronic irritability of the brain, characterised at the outset by restlessness and a tendency to persistent flexion of the muscles and contraction of the pupils, cool surface, feeble and slow pulse, and subsequently by mental decay or complete fatuity, paralysis, or epilepsy. This condition has been supposed to be associated with laceration of the grey matter of the brain."

Many of the complications above referred to were the direct results of suppurative processes fostered and encouraged by the system then employed of dressing wounds with wet lint and waterproof sheeting. Thorough disinfection of the skin and wound, and the use of aseptic dressings, will certainly prevent the occurrence of periostitis, caries, and necrosis in most of these cases, although the more remote effects of the concussion or even laceration of the brain, persistent pain at the point struck, vertigo, imbecility, epilepsy, and impairment of the special senses, will still be experienced. The indications, therefore, for the treatment of these cases of contusion of the cranial

bones without fracture of either table are obvious, and need no description; a thoroughly aseptic condition of the wounds is the important end to be attained.

If gunshot fractures of the cranial bones be classified, as is usually done in works on surgery, according to whether one or both tables are implicated, and as being with or without depression of fragments, the most common fractures of the skull met with in war hospitals—omitting cases of penetration—are those in which both tables are

FIG. 67A.
Slight depression of outer table.—*Netley Museum.*

fractured with depression (figs. 67, A and B). Other varieties of fracture are produced by projectiles, but they are comparatively exceptional. Fractures of either table alone *may* occur, but fractures of the outer table without injury to the inner, by gunshot, are extremely rare, except in one or two situations, as the frontal sinuses and mastoid processes, where the two tables are separated from each other by some considerable interval. Otis is disinclined to admit the possibility of this kind of injury, except at the points mentioned, and Erichsen and Delorme agree with him, but exceptional cases do occur (see figs. 68, B and C). On the other hand, fractures of the inner table alone are fairly common. Contusion of the outer table by

a bullet, while producing in it no fracture or fissure, is sufficient to cause extensive fracture of the inner table with displacement and depression of fragments, and with, perhaps, laceration of the membranes and of the brain. The injury to the inner table is, of course, still more extensive, and the depression of its fragments more marked, when the outer table is fractured as well, although not depressed.

FIG. 67B.

Depression of inner table in case shown in Fig. 67A.—*Netley Museum.*

The immediate diagnosis of separation and depression of the inner table in cases of mere contusion of the skull, or even in those accompanied by such slight fractures of the outer table as do not permit of exploration with a probe, is difficult. If, on the other hand, time be allowed to elapse, signs of brain irritation may supervene, and indicate the nature of the injury. In considering the probability of fracture and depression of the inner table in these cases, the surgeon must remember the fact, already mentioned many times, of its great liability to extensive damage without apparent injury to the outer table. Bergmann has proved, Chauvel remarks, that the more the site of the violence is localised, and the fracture of the outer table circumscribed, the more certain we may be that the inner table is fractured extensively. Attention has been drawn to the higher pitch of the percussion note over the area of separation of the inner table than that given at other points on the skull. La Motte, Stromeyer, and others as far back as Paré's time, suggested percussion with a probe for the diagnosis of this condition. Possibly this method may be of some use; but mere suspicion or probability of de-

tachment of the inner table, when the outer is not visibly injured or depressed, would hardly justify the use of the

FIG. 68B.

Grooving of outer table of skull without injury to inner table, by gunshot. See Fig. 68C.—*Netley Museum.*

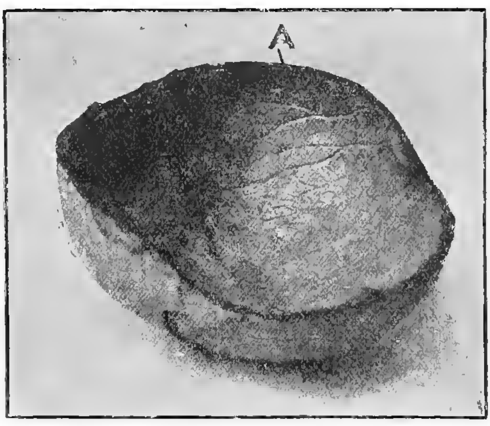


FIG. 68C.

A. Inner table opposite groove in outer table.—*Netley Museum.*

trephine until signs of meningitis or of brain mischief presented themselves.

In some few exceptional cases the depression of the inner table may be so decided as to cause paralysis of muscles on the opposite side of the body. In these cases tre-

phining should be performed for the purposes of elevation or removal of fragments, or for washing out blood clots and the ligature of bleeding vessels. When, later in the case, symptoms of cerebral or meningeal inflammation, or of compression from hæmorrhage, supervene, similar treatment should be adopted without delay.

Fissured fractures of both tables, with or without obvious depression, are extremely common; and, although depression of the outer table may not be apparent or may be

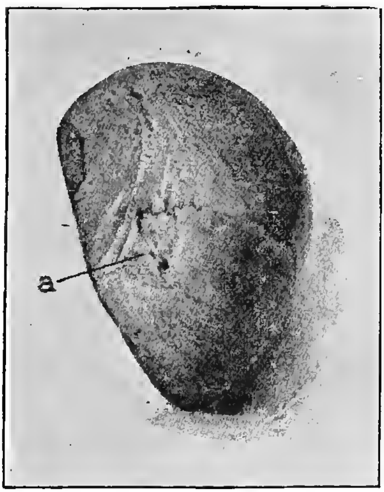


FIG. 69A.

Fissured fracture of outer table at *a*, without depression.—*Netley Museum.*

FIG. 69B.

Fracture with depression of inner table at *b*.—*Netley Museum.*

very slight, depression of the inner table, and much greater damage to it than to the outer, may be inferred as certain (figs. 69, A and B). In the American War 2911 cases of this kind are recorded, of which 1826 proved fatal. On account of the depression and excessive splintering of the inner table, and because more or less extravasation of blood must occur, causing more or less compression of the brain, immediate trephining is indicated in these fractures.

In some cases, especially when the bullet impinges on the skull obliquely, the missile may become split against the edge of the fissure, one part entering the cavity of the

cranium, and the other passing on or lodging beneath the scalp (fig. 70). In still rarer cases, when this has occurred, the plate of bone corresponding to the aperture through which the portion of bullet entered has so completely recovered its level by its resiliency as to leave no trace of the entrance of the foreign body (fig. 71). The museum at

FIG. 70.

Gunshot fracture of skull; part of the bullet was found within the cranium, and part under the scalp, as shown here.—*Netley Museum.*

Netley contains a specimen of each of these surgical curiosities; but such cases are not likely to result from the hard-mantled small-bore bullets.

Grooving of the external table and diploë were frequently produced by the old leaden bullets striking tangentially; this class of injury to the skull is equally probable with the new bullet, and, as in other cases, the injury to the inner table is likely to be of greater extent than that of the outer.

Depressed fractures of both tables are very common (fig. 72). They are usually the results of shell fragments,

or of small-arm bullets at low rates of velocity. The depression is usually cup or cone shaped, with fissures extending from the edge of the cup to the centre of the depression, dividing the plate of bone into two or more triangular fragments. The comminution accompanying these fractures may be very severe, and fissures may radi-

FIG. 71.

The bullet was found within the cranium, but the aperture in the skull had almost closed.—*Netley Museum.*

ate from them for long distances; the use of the trephine is always indicated in this class of case.

Small-arm bullets travelling at high and medium velocities, and striking more or less perpendicularly to the surface, cause penetration or complete perforation of the skull. The entrance apertures in these cases are clean-cut and punched-out circular holes; while the exit aperture, when perforation takes place, is more splintered and irregular, from increased fracture of the outer table. The outer table at the entrance side is cleanly pierced and circular; while the inner table (fig. 73) is splintered, more largely

fractured, and spiculæ are driven into the dura mater and brain. At the exit side in the skull the reverse of this

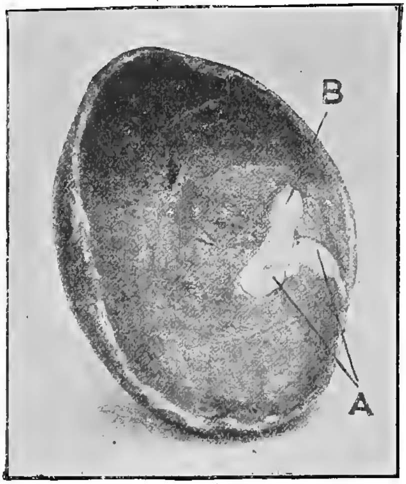


FIG. 72.

Gunshot fracture of skull, inner surface. The fragments of the inner table (A) are much depressed. B is a trephine hole.—*Netley Museum.*

FIG. 73.

Inner table at entrance side.—*Netley Museum.*

condition takes place; here, the inner table is cleanly punched out, and the outer table is irregularly fractured and to a much greater extent, with fragments driven out-

wards into the scalp (fig. 74). In fact, in perforation of the cranial bones by bullets, it is always found that the table through which the projectile passed last is the more severely fractured—the inner table on the entrance side, and the outer table on the exit side.

The widespread fissuring, not only between the exit and entrance holes, but also in all directions and quite unconnected with them, the bursting apart of the sutures, and the enormous injury to the brain resulting in cases of complete perforation of the skill, have been already re-

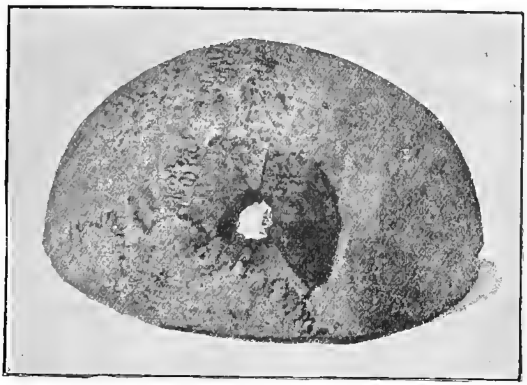


FIG. 74.

Outer table at exit side.—*Netley Museum.*

ferred to. Death is usually instantaneous; but in the American War seventy-three cases of complete perforation of the skull by bullets lived to come under treatment in the field hospitals, and fourteen of the men were subsequently discharged as pensioners, while at least one lived for nine years after the receipt of the wound. The patients who survived complete perforation of the skull by rifle-bullets were, during the remainder of their lives, "quite incapacitated from earning a livelihood by physical or mental exertion. Vision was destroyed or greatly impaired in most of them; complete deafness resulted in one case, hemiplegia in one case, paraplegia in another, local paralysis in three others, and nearly all the patients suffered

from headache, vertigo, defective memory, and various forms of impairment of the mental faculties." [1]

According to von Coler, only 48 per cent. of the cases of injury to the bones of the skull by rifle-bullets, in the war of 1870–71, had the cavity of the cranium laid open. In future wars the proportion will be very different. Omitting indirect and grazing hits, almost every bullet which hits the skull, up to a range of 2200 yards, will perforate it, and at about 2900 yards they will penetrate and remain lodged. The destruction produced in the skull and brain by modern bullets is so extreme, even at long ranges, that comparatively few patients will survive long enough to reach the field hospital for treatment, and for the large majority of those who do, treatment will be unavailing.

Patients who survive gunshot fractures of the skull usually suffer from loss or great impairment of the special senses, epilepsy, imbecility, or other signs of local or general interference with the cerebral functions. After the American War, partial or complete loss of vision was one of the most common of the remote effects observed. Deafness was a less frequent complication, and it was generally associated with impairment of other special senses; while a large number of the patients suffered from epilepsy and various forms of paralysis, and some from insanity.

Concussion and Compression. — In the condition of shock, collapse, and unconsciousness which usually follows gunshots of the skull, whether they cause fractures or mere contusions, it is difficult or impossible to differentiate the symptoms which may be due respectively to concussion or to compression of the brain. Depression of the outer table may not be obvious, but compression of the brain may be present nevertheless, either from displacement of the inner table or from hæmorrhage within the skull. MacCormac [2] considers that symptoms of concussion are rare in cases of gunshot of the head, while those of compression are more frequently observed. The causes of compression are depressed fragments of bone, and hæmor-

[1] Otis.

[2] Article on Gunshot Wounds, Heath's "Dictionary of Surgery," 1886.

rhage either above or below the dura mater. More or less hæmorrhage must take place in all cases of fracture of the skull, and, moreover, extravasation of blood between the dura mater and the bone may be produced by mere contusion without fracture. If the amount be small, and if the effusion take place slowly, no symptoms of compression may arise; but in the cases under consideration the hæmorrhage is usually rapid, and the signs of the condition it gives rise to well marked. The middle meningeal artery and its branches are the vessels usually implicated when the bleeding is severe. With or without obvious depression of bone, the presence of the combined symptoms of compression and concussion necessitate the use of the trephine as soon as the patient has recovered from the collapse which usually occurs to a greater or lesser extent on the receipt of the injury, with a view to the elevation of bone if it be depressed, and for the removal of coagula and the ligature of bleeding vessels if hæmorrhage has been the cause.

Certain other complications besides compression, concussion, and hæmorrhage within the skull, which are primary and immediate, may supervene as secondary results in cases of gunshot of the head: they are hernia cerebri, abscess of the brain, encephalitis, and meningitis. Of these complications it may be said that they are due to septic infection of the wound when one exists. Certainly with the onset of suppurative changes in the wound, some or all of them will surely occur. The preventive treatment, therefore, to be directed against them will consist in such methods of treatment of the wound as will ensure its continued aseptic condition. Almost all fatal gunshot injuries of the head, the subjects of which do not die where they fall on the field, prove fatal from one or other, or a combination, of these complications.

Hernia Cerebri is a fairly common and a very fatal complication of gunshot fracture of the skull. It is due to an increase of the intra-cranial pressure depending upon encephalitis or meningitis, and is frequently accompanied by abscess in the brain substance. The dark-brown or

reddish-grey tumour which protrudes through the opening in the cranium may be formed of true brain matter or of inflammatory exudation material, possibly of a mixture of these substances. Of 55 cases detailed by Otis, 44 died. The time after the receipt of the injury when this complication makes its appearance varies from three or four days to as many weeks, or even longer.

The Treatment to be adopted should consist in endeavours to render the tumour and its surroundings aseptic. The part should be washed or irrigated daily with 1–40 carbolic solution or other antiseptic, gently dried, and have iodoform or boracic acid powder dusted over it; no wet dressing should be used. Operative interference for the removal of the tumour is dangerous as well as useless, nor should pressure be applied to it. The usual dry gauze and wool dressings should be employed. In a small percentage of the cases the tumour recedes, and recovery takes place; but the usual termination is death from an extension of the inflammatory mischief within the cranium which originally produced the complaint.

Abscess of the Brain is a fairly common sequela of gunshot fractures of the skull, and a very common one in those cases where suppuration occurs in the wound. In the absence of infection of the wound, abscess of the brain need hardly be feared in otherwise healthy men. No doubt, meningitis, encephalitis, and abscess of the brain do arise "idiopathically," as it is called, in patients predisposed to these complaints, and in cases of injury to the head without wound of the scalp, when infection from without is impossible; but it may be taken as a very general rule that suppuration at the seat of injury is the cause of these complications when met with amongst the wounded in war hospitals. This complication usually begins to show itself by symptoms between the second and third weeks after the receipt of the injury, but in exceptional cases it may commence during the first week. The symptoms are often vague and uncertain, and the diagnosis difficult. It frequently happens that they are at first masked by those of the encephalitis and meningitis, which are so likely to

precede and accompany the formation of a brain abscess. The most marked signs of the complaint are occasional rigors, or merely a feeling of cold, vomiting, twitchings of certain muscles or convulsions, paralysis of sets of muscles supplied by the affected part if in a motor area, optic neuritis, subnormal temperature, and slow pulse. Perhaps the two last are the most typical symptoms of the disease. Optic neuritis is a valuable sign, but it is not always present with abscess of the brain, and it may occur without it.

The only treatment which affords any hope of recovery is that by operation. Trephining should be performed, the abscess sought for by means of a hypodermic needle, and, if found, opened, irrigated, and drained, precisely as are abscesses in other situations. It usually happens that the site of the abscess corresponds to that of the injury, but this is not invariably so. It will then become a grave question for consideration whether or not the indications afforded by the twitchings or other conditions of certain groups of muscles, or, if convulsions be present, the observation of which muscles these commence in, are sufficiently clearly marked to warrant a diagnosis of brain lesion in a particular motor area at a distance from the wound, and whether the trephine should not be applied over the area to which these local symptoms point. It should be remembered that laceration and injury to the brain do not as often occur, from mere contusion, at the point immediately beneath the part struck as at the point directly opposite. In cases, therefore, in which the spasm, twitching, or contraction of muscles is observed on the same side as the injury to the head, it is quite probable that the laceration of the brain, the abscess, or the hæmorrhage causing compression has occurred at the opposite side. Many cases are on record where the localisation symptoms affecting muscles did not correspond to the site of injury, and where the proper treatment could only have been carried out by the guidance of these symptoms. In the absence of localisation symptoms the trephine should be applied at the site of injury, and certainly so when both the symptoms and the site of the injury indicate the same

area of lesion. Motor symptoms, if thoroughly understood, cannot mislead; while an inference that lesion secondary to an injury must be in its immediate neighbourhood may be wrong. When, therefore, the motor symptoms are distinct, and the surgeon has confidence in his interpretation of them, they should be followed.

The Treatment of Gunshot Fractures of the Skull.—From what has already been said regarding the part sepsis of the wound plays in the causation of fatal complications in cases of fractures of the skull, the principles on which the local treatment must be carried out will be evident. Perfect aseptic conditions are probably more important and necessary in this than in any other class of gunshot injury. Suppuration in a wounded joint is a sufficiently serious complication; it may cause the loss of a limb, it may even cause the death of the patient. But septic encephalitis and meningitis are amongst the most fatal conditions met with in surgery, and infection from the wound is almost invariably the source from which they aise. There is nothing whatever inherent in the brain or in its membranes which renders them peculiarly susceptible to inflammatory processes. Both experimental research and clinical experience have proved that the contents of the cranium may be exposed and handled and incised, sutured, and washed with antiseptic solutions, just as other parts of the body may be, without causing them to manifest signs of injury from these procedures, the sole protective condition being, in them as in the others, that they are not contaminated by micro-organisms.

From contamination of this kind proceed those complications of head injuries which make them anxious cases for the surgeon, and, for the most part, fatal to the patients. Asepsis, therefore, is the main object to be kept in view in the local treatment of the wound. A large area around the wound, or, better still, the whole head, should be shaved. The wound should be irrigated with an antiseptic lotion, 1–40 carbolic solution for choice, and covered with a pledget of cotton-wool, wet with the same lotion, while the scalp is being disinfected by washing with hot

water and soap, and scrubbed with a nail-brush, then washed with turpentine or ether, and again with 1–20 carbolic solution. The wound should again be irrigated with the weaker solutions, and, if no operative procedures are required, dusted with iodoform, and the gauze-wool dressings applied. If the case be one of fracture, any loose spiculæ of bone which may be visible should be removed.

When there is a wound of the scalp, the treatment should certainly be carried out on these lines; and even in cases of severe contusion without wound, the head should be shaved, with a view to future events when the application of cold may be deemed necessary. It is well also to remark that ice-bags for use with head cases where a wound exists, should always be made of india-rubber or some similar material capable of being rendered aseptic, and not of animal tissues, such as bladders and the like, which are sure to be septic. With thorough asepticisation of the wound, drainage will not be required.

All cases of head injury should be treated in a darkened room, if possible, and with as perfect quiet as can be obtained. A low diet only should be allowed, and no stimulants permitted. The bowels should be kept freely open by means of calomel, croton oil, or salines. Even with an aseptic wound, certain complications may arise, such as compression due to hæmorrhage from a large vessel, or symptoms depending on laceration of the brain substance beneath or at a distance from the site of injury; the latter is an extremely grave condition, and usually fatal in its results. These complications should be treated on the general principles of surgery applicable to such cases—the former by the operation of trephining when the motor symptoms indicate the probable locality of the hæmorrhage, and the latter by the means already referred to, together with the use of bromides, and perhaps chloral, with the application of cold to the head by means of the ice-bag. If these do not suffice, and the symptoms of encephalo-meningitis increase, the trephine will be the only resource which can save the patient's life, and its employ-

ment will be justified if the affected areas be denoted by the groups of muscles involved.

Foreign Bodies lodged in the Brain.—Bullets, small spiculæ of bone from the entrance side, and portions of the patient's head-dress are the foreign bodies most likely to be found lodged in the brain. If they be perceived, their removal should, of course, be proceeded with, but any prolonged searching for them is not permissible. The spiculæ of bone which are driven in are usually extremely small, and their detection and extraction are difficult or impossible. A bullet which has lodged will probably have traversed the brain and have been stopped by the bone at the other side, and attempts to recognise its position at so great a distance from the surface are sure to be attended with extreme danger of causing further damage. Exploration for the detection of a bullet should be made by gently passing a blunt probe along the track to whatever depth the surgeon may consider justifiable, but it should be confined strictly to the line of the channel in the brain, no lateral motion being given to it. If the bullet be found, it should be removed with a suitable forceps. The diameter of the entrance aperture made in the skull is often scarcely, if at all, larger than that of the projectile; it may therefore be necessary to enlarge the opening in the skull to permit of the extraction of a bullet when held in the jaws of a forceps.

A bullet which has not sufficient velocity to make an exit on the far side of the skull, may yet have enough energy to cause a fracture at that situation. In cases of this kind trephining for the removal of the missile has occasionally been done over the second site of fracture, sometimes with success, but sometimes the bullet has not been found lodged under the trephine hole. Larrey operated, and removed the bullet, in a case where there was no second fracture on the opposite side of the head, but the patient complained of pain there. Death, however, is not a necessary consequence in cases where the bullet cannot be extracted. Many instances are on record in which bullets have lodged in the cranial cavity without producing a fatal

result, though few are known, as Otis remarks, like those reported by Larrey, of bullets becoming encysted and causing no inconvenience for years. Delorme suggests, on failure to find the bullet at the first attempt, placing the patient's head in the position which tends to permit of its approaching the aperture by the force of gravity, and making a second exploration after a day or two. With modern methods of treatment of the wound, and the absence of suppuration, these chances of a lodged bullet becoming encysted and producing no symptoms are increased.

The Operation of Trephining for Gunshots of the Cranium.—The question of the advisability of the operation of trephining in cases of gunshot fractures of the skull in war hospitals is one which has led to much difference of opinion amongst army surgeons, and the opponents of the practice have hitherto had a good deal of evidence in favour of their view. The results of the operation have certainly not been encouraging. Sir Thomas Longmore says of his own experience in the Crimea: "The trephine was used successfully in only 4 cases out of 28. On the other hand, 14 men with depressed gunshot fractures of the skull recovered without trephining." And further, he remarks that "trephining with a view to prevent anticipated consequences of a gunshot injury of the head, and speculative trephining in general, are not justifiable operations." In the French report by M. Scrive it is stated that trephining was for the most part fatal. Chenu, in his history of the campaign in Italy of 1859, states that, amongst 779 cases of wounds and injuries of the head, trephining was only performed 9 times in the French hospitals, and that 7 of the cases died. Stromeyer, who in the early part of his career advocated trephining in complicated fractures of the skull, has recorded that he was led to abandon the practice. He mentions that after one of the battles in Schleswig-Holstein there were eight gunshot fractures of the skull with depression and more or less cerebral symptoms. In all these, with one exception, the detachment of the fractured pieces was left to nature, and all recovered. He also states that during the Franco-German War the trephine

was only used twice in the large hospital at Versailles, and that both cases terminated fatally.

As regards our own records, it is found that no soldier was invalided to England from India after the Mutiny on whom the operation of trephining had been performed, from which we may infer either that the operation was not performed during that campaign, or that the cases which had been subjected to it did not live to reach home. At the end of the last century a gunshot injury of the head was supposed to be of itself a sufficient indication for the use of the trephine. But at the close of the Peninsular War, English army surgeons had mainly limited the operation to cases where (1) a depressed fragment of bone or effused blood was producing an interruption of the cerebral functions; (2) where points or edges of bone were penetrating the membranes or brain substance, and no simpler means of elevation or extraction sufficed; or (3) where a cerebral abscess had formed within reach of evacuation. The favour in which the operation was formerly held by military surgeons has steadily decreased, and it is now evident that it has been less and less resorted to since the Peninsular War.

At the present moment, owing to the improved methods of wound treatment and the consequent immunity from infective disease attending all operations, the pendulum of opinion is swinging perhaps to the other extreme, and we find Mr. Victor Horsley[1] recommending operation in all cases of depressed fracture of the skull, simple or compound, and with or without symptoms connected with brain lesion or compression. In this Mr. Horsley speaks as a surgeon of modern views, and, though not referring particularly to gunshot injuries, his advice is quite applicable to them. The present methods of wound treatment will render the operation a safer one in our hands than it was in those of the surgeons of pre-antiseptic times, and when we find a fragment of bone depressed, and probably lacerating the brain or its membranes, accompanied or not by nervous symptoms indicative of brain irritation or com-

[1] "Surgery of the Central Nervous System," 1890.

pression, we should consider it our duty to interfere by operation for the removal of what appears to us to be the offending or threatening condition.

In fact, the change which has occurred in the opinions of surgeons regarding the use of the trephine in head cases is the oft-told story over again. In earlier days no surgeon dared to interfere with a serous membrane, if he could avoid it. The peritoneum, the synovial covering of joints, the pleura, the membranes of the brain, were by the older surgeons severely left alone. But now these very structures are the fields of the greatest successes of modern surgery, and no surgeon hesitates to operate merely because he knows that they must be implicated in his procedures. The membranes of the brain form no exception to the carrying out of these more advanced ideas as to what aseptic work is capable of bringing to a successful issue, and therefore trephining in gunshot injuries of the skull may, in future, be looked to for better results than were achieved by it in Peninsular and Crimean days.

As regards the Time when trephining should be performed after the receipt of the injury, the American statistics show a mortality of 69.6 per cent. for the primary, 56.6 per cent. for the intermediary, and 23.5 per cent. for the secondary operations. But the indications obtained from these ratios should not be relied upon; the sooner the operation is done the better. This follows from the nature of the cases, and the conditions for the relief of which it is undertaken. If the operation be undertaken to prevent the onset of symptoms of brain irritation, the sooner that danger is obviated the better, and if for the removal of the causes of compression and of nervous symptoms actually present, no time should be lost in placing the patient in the only position where recovery is possible.

Mr. Victor Horsley's experiments on animals[1] have proved that, in cases of rapid death from gunshots of the brain, the fatal result is due to paralysis or interference with the functions of the respiratory centre, and that life may be maintained for a considerable time if artificial res-

[1] See Paper read before the Liverpool Medical Institution, 1893.

piration be commenced sufficiently early. But I fear that these researches will not help us much towards saving life on the battle-field, though they certainly indicate a line of treatment under particular circumstances.

Wounds of the Neck.

Sword and Bayonet Wounds of the neck are extremely rare injuries in warfare. Only 9 cases of this class, with 1 death, are recorded by Otis during the American War, and 13 amongst the Germans in 1870–71.[1]

Gunshots of the Neck.—Even excluding from consideration for the present injuries of the cervical spine, a large proportion of gunshot wounds of this region prove rapidly fatal on the field from laceration of the large vessels of the neck, and from serious interference with the processes of respiration and circulation by wounds of the pneumogastric, sympathetic, and phrenic nerves. Of those who survive to reach the field hospitals but who eventually die, Chauvel declares that "over 28 per cent. die within the first three days, and more than half in the first week; while death is rare after the third week." The death-rate following wounds of the neck in the Franco-German War was 13 per cent., and in the American War 12.6 per cent.

The Complications of Gunshots of the Neck.—Most authorities on military surgery have remarked on the curious manner in which the large vessels of the neck occasionally escape injury when the site of the wound and the direction of the bullet track would appear to indicate a certainty of their being lacerated. Williamson, of the 64th Regiment, and Neudörfer have suggested, as an explanation of this, the looseness and mobility of the structures in this region allowing them to yield or slip aside; but, as already stated, this immunity of large arteries and veins from injury is not likely to be observed in wounds produced by small-bore projectiles.

Wounds of the Carotid Trunks and their large Branches.—When the carotid arteries themselves are wounded, death

[1] Chauvel et Nimier.

usually occurs immediately on the field, but occasionally cases of this class reach the field hospitals. The vessel should be ligatured above and below the laceration, and divided between the ligatures, if complete section has not already been produced. The longer this operation is postponed, the greater will be its difficulties, in consequence of the disturbance and distension of the parts by the diffuse aneurism which is almost sure to form beneath the skin. For lacerations of the branches of the vessels in the neck, the indications for tying the bleeding points in the wounds are probably even more marked than in cases of hæmorrhage elsewhere. Styptics and pressure are quite useless in these cases, and ligature of the main vessel below fails in a large proportion of them. The latter operation gave a mortality of 78 per cent. in the American War, and 68 per cent. in the war of 1870–71. Hæmorrhage from either of the thyroid vessels is usually very profuse, and if the escape outwards of the blood be in any way prevented, dangerous difficulty of breathing will result from effusion of blood within the loose tissues of the part causing pressure on the trachea. The wound should be enlarged if necessary, the clots turned out, and direct ligatures applied. Pressure on the trachea, in cases of wounds of the vessels of the neck, is not confined to those in which the thyroid arteries are lacerated, but may occur when any of the arteries are injured, and the effused blood does not find a ready outlet, either in consequence of the apertures in the skin and those in the deeper layers of structures not corresponding, or when the hæmorrhage has been temporised with by treatment by pressure.

The necessity of treating wounds of the branches of the carotids by direct ligature in the wound is very strongly stated by Otis, when he remarks in this connection: "If the indolent or timid surgeon, to control bleeding from the minor branches of the carotid, prefers to stuff the wound with styptics, or to perform the easy operation of tying the common trunk, rather than to seek, in the difficult anatomy of the maxillary or thyroid regions, to place double ligatures at the bleeding point, he may temporise, or may

associate his name with the necrology of ligations; but if his patient recover, it will generally be found to be under circumstances in which the surgeon's operative intervention was uncalled for."

When the wound in the neck is at or above the level of the angle of the lower maxilla, in the parotid region, the hæmorrhage may be very difficult to treat successfully, coming as it may do from the main trunks of either the internal or external carotid, or from the large branches of the latter, and it is often not easy to diagnose from which of these sources it proceeds. The ideal treatment is to apply a double ligature in the wound, but this may be difficult or impossible. If ligature of the bleeding points cannot be carried out, Delorme recommends that the suggestion of Richet should be followed, that the bifurcation of the common carotid should be laid bare, compression applied first to the external and then to the internal carotid, and a ligature placed on the vessel, compression of which controls the hæmorrhage. If compression of neither artery singly arrests the hæmorrhage, both trunks should be tied. But neither these procedures nor ligature of the common carotid will, in all cases, prevent a recurrence of the bleeding from the distal end of the wounded vessel, and when these uncertain measures are being employed they should be supplemented by the application of graduated pressure in the wound by pledgets of antiseptic gauze, the bullet wound in the skin having been previously enlarged to permit of their efficient action.

Wounds of the Internal Jugular Vein are very grave injuries. In the American War 15 cases are recorded, of which 14 had a fatal result, secondary hæmorrhage or pyæmia being the immediate cause in most of them. Fischer has collected details of 60 cases with a death-rate of 28.3 per cent., 19 of them being complicated with wound of the carotid. If the wound be in a situation in which the double ligature above and below the laceration can be applied, this should be done; if not, graduated pressure through an enlargement of the skin wound must be substituted.

Arterio-Venous Aneurism. — When both the internal jugular and carotid vessels are wounded by a bullet, and, more especially, when the injury is the result of a sword or bayonet thrust, an arterio-venous aneurism is a possible sequela. Several cases of this kind are already on record, and one was in Netley Hospital in 1895. Private P. A., 2nd Royal Irish Regiment, was invalided from India, and arrived at Netley in November 1895. He had been struck in the neck by a splinter of a bullet. Severe hæmorrhage immediately took place in jets to a distance of three yards, according to the man's own statement. "A comrade tied a flat stone over the wound, and no further bleeding occurred while the man was being removed to the hospital." The wound was half an inch long, and situated over the common carotid, two and a half inches below the mastoid process, on the right side. The splinter, which was half an inch long, was found in the wound and removed; the wound was disinfected and dressed, but not sutured, pressure being applied to control the hæmorrhage. Healing was complete in fourteen days. Soon after the receipt of the injury the voice was weak and hoarse, but it improved later. The man's condition on admission at Netley was as follows: There was a tumour about the size and shape of a half walnut, showing a cicatrix, over the line of the common carotid at the point above defined; it had an expansile pulsation, a continuous thrill was to be felt, and a very violent rumbling bruit was to be heard with the stethoscope synchronous with the pulse, while a venous hum was audible during the intervals. The patient said he felt and heard a buzzing sensation on the right side of his head, and that he could not sleep on the right side. He suffered from shortness of breath, and occasionally woke up with a feeling of impending suffocation. He also complained of headache and pain in the cardiac region. He was slightly hoarse, and, on examination with the laryngoscope, it was found that the movement of the right vocal cord was limited in the direction of approximation. This was clearly a case in which a communication existed between the internal jugular vein and the common carotid. No treatment

was adopted while at Netley, and the man was discharged from the service. He was in excellent general health, and the subjective symptoms felt by him were very slight, considering the extraordinary loudness of the bruit in the neck. Interference by operation in these cases is not to be recommended; it usually either produces a fatal termination, or fails to cure the complaint.

Wounds of the Nerves of the Neck.—The sympathetic nerve or any of the cervical nerves may be implicated in gunshots of the neck, and the symptoms which result will be loss of motion, or of sensibility, or of both, and interference with the functions of the parts supplied by the particular nerve trunks injured. Wound of the sympathetic from this cause can hardly occur without such other complications—injury to the spinal cord, large vessels, air-passages and œsophagus—as will prove rapidly fatal. But some cases are on record of patients who survived, and in whom symptoms of lesions of this nerve were observed.

Dr. S. Weir Mitchell[1] describes one seen by him during the American War. E. Mooney was wounded in the neck by a bullet, at Chancellorsville, on 3rd May 1863. The bullet entered on the right side, one and a half inches behind the ramus of the jaw, at the anterior edge of the sterno-mastoid muscle, and passed out at the angle of the jaw on the left side. Articulation and deglutition were much interfered with and extremely painful for some weeks. Some improvement in these respects began after a month, and continued until eventually he could swallow as well as ever, but the voice always remained a little hoarse. In July 1863, the pupil of the right eye was much contracted, and the eye itself appeared "to be smaller than the other, and tilted out of the usual position"; the conjunctiva was red, and the man saw flashes of red light with the right eye. Exertion made the right side of the face to flush, while the left remained pale. By October 1863 all his peculiar symptoms had disappeared, and he returned to duty.

[1] "Gunshot and other Injuries of Nerves," Philadelphia, 1864.

Weir Mitchell goes on to discuss the question, "Was this a case of wound or injury of the cervical sympathetic," and decides that, in his opinion, it was so. No mention is made in these notes of retraction of the eye-ball, but possibly the fact that the eye looked smaller than its fellow may have been due to this condition. When the cervical sympathetic is injured to the extent of complete paralysis, the pupil is contracted, the eye-ball retracted, and there is an increase of the sweat secretion of the face on the affected side; when the injury causes only irritation of the nerve, the symptoms are dilatation of the pupil and protrusion of the eye-ball.

Wounds of the pneumogastric are also usually accompanied by such severe hæmorrhage, in consequence of the close relationship between the nerve and the carotid artery and jugular veins, as to be immediately fatal; but some few cases have been observed in which this did not occur. The symptoms noted have been irregularity and rapidity of the pulse and turbulent action of the heart, difficulties of articulation, respiration, and deglutition, and, later, hepatisation of the lung and pneumonia. When death does not occur from the hæmorrhage accompanying the nerve lesion, it usually results secondarily from pneumonia and bronchitis.

Mr. Makins, of St. Thomas's Hospital, reported, at the Clinical Society,[1] a case of division and immediate suture of the left vagus, during an operation for the removal of an epitheliomatous tumour from the neck. The nerve was divided just above the centre of its cervical portion, and no obvious symptoms, either immediate or remote, beyond paralysis of the muscles supplied by the recurrent laryngeal, were observed. The laryngeal paralysis and the quality of the voice rapidly improved, and two months later nothing remained but some want of power in abduction of the vocal cord and a little hoarseness of the voice. It was pointed out that "the case supported the opinion lately expressed by Roswell Park as to the comparative safety of dividing one vagus if necessary, and also offered

[1] *Lancet*, 16th May 1896.

some evidence as to the possible recovery of function if immediate suture were performed."

A few cases of injury to the phrenic nerve by bullets have been observed. The symptoms caused by these lesions are hiccup, a sensation of constriction around the body, and dyspnœa from paralysis of one-half of the diaphragm.

But wounds of the nerves of the neck by projectiles are principally of interest from the physiological and pathological points of view: the surgeon can do nothing for their repair, beyond endeavouring to keep the wound aseptic. It usually happens in these cases that he is fully occupied in the treatment of the other grave injuries which so often accompany them.

Wounds of the Air-Passages.—Wounds produced by bullets in the larynx and trachea are usually clean-cut perforations. The large vessels are frequently injured when the missile travels from side to side, and a wound in an antero-posterior direction is liable to include laceration of the carotid trunks, fracture of the cervical spine, and injury to the spinal cord. There is usually no room for doubt in the diagnosis of these cases: the situation of the wounds, the passage of blood mixed with air from the orifices, and the extreme dyspnœa are sufficient evidence of their nature. The immediate dangers to life which present themselves in wounds of the air-passages are hæmorrhage and asphyxia, the former from injury to vessels in the neck, and the latter from the passage of blood into the smaller air-tubes. The more remote dangers are due to the supervention of inflammatory processes such as pneumonia and œdema of the glottis. The latter complication may occur at a late period, even when the wound has nearly healed, and all probability of the onset of this complication has apparently passed away.

The Treatment of wounds of the larynx and trachea must be proceeded with on the principles of general surgery. Severed vessels should be ligatured in the wounds. If the wound be in the front of the trachea, and produced

by a grazing bullet, where there is little or no loss of substance, it should be closed with sutures, provided there are no signs of respiratory difficulties; otherwise sutures should not be used. If dyspnœa be present—and this, in a marked degree, may accompany mere contusions of the larynx—tracheotomy must be performed. Delorme recommends "preventive tracheotomy" in all cases of wound and contusion of the larynx as one of the first things to be done; and if this be not always required, the surgeon should at least be prepared to perform the operation at a moment's notice.

Wounds of the œsophagus may accompany gunshots of the trachea, and then, as well as in cases where the pharynx or the upper portion of the larynx is implicated, the patient will be unable to swallow, and feeding may be a difficulty. Under these circumstances the best way to administer food will be by means of a small red rubber tube, or a large Jacques catheter passed into the stomach from the mouth or nose. In this way the danger of food getting into the lungs and air-passages will be avoided. Operative interference to close the wounds is seldom possible in cases of gunshot of the œsophagus. Wounds of the œsophagus and pharynx, as well as those of the air-passages, often prove fatal from secondary lung complications.

The Permanent After-Effects seen in patients who recover from gunshots implicating the neck are usually cicatricial contractions or fistulæ of the air-passages due to injury to the cartilaginous portions of the larynx and trachea, and like conditions of the œsophagus when this tube has been wounded. Cicatrices and fistulæ of the larynx and trachea may interfere with phonation in all degrees varying from slight hoarseness to complete loss of voice, frequently accompanied by more or less difficulty of respiration, from which, together with the effects of cold air entering through the abnormal openings, secondary lung affections may arise. When nerves are injured, either by contusion or direct section, the effects are seen in paralysis of the particular muscles, or in loss or impair-

ment of function of the parts supplied by them, conditions which are most apparent by interference with the voice and with the movements of respiration.

Wounds of the pharynx and œsophagus, even when not accompanied by such complications as lacerations of large blood-vessels and injuries to the cervical spine, are liable to give rise to a very fatal form of acute cellulitis of the neck, and later to stricture and fistulæ. The treatment of all these sequelæ of wounds of the neck is to be pursued on the lines indicated by the general principles of surgery: there is nothing peculiar in the procedures required for their cure or amelioration when met with in war hospitals to differentiate them from the treatment necessary for similar cases in civil practice. Fistulæ may remain open for long periods, but tend to close eventually without special treatment.

Gunshot Wounds and Injuries of the Spine.

The gravity of gunshot wounds of the spine depends upon the region of the column affected and on what parts of the particular vertebræ are implicated in the injury. As a rule, the prospect of recovery, and the duration of life in fatal cases, diminish as the site of injury to the spinal bones approaches the head. The higher up the region in which the wound occurs, the graver is the prognosis in gunshots, as in cases of fracture-dislocation seen in civil practice. And again, the more remote the fractured portions of the injured vertebra are from its central canal, and therefore from the spinal cord, the less may be considered the danger of the case. When cases of gunshot of the spinal column recover, either partially or completely, they are almost invariably found to be those in which only the projecting processes of the bones are fractured. Fractures of the spinous and transverse processes of the vertebræ may be recovered from, although often with permanent impairment of the parts below the seat of injury; but fractures of the bodies and laminæ of the vertebræ are almost always fatal from injury of the cord, after an interval

more or less prolonged varying with the region in which they have occurred.

Gunshot wounds of the spine are frequently complicated by injuries of important structures in the neck or by penetrating wounds of the chest or of the abdomen, conditions which tend greatly to increase the gravity of cases already sufficiently dangerous on their own account.

Otis gives the death-rates following gunshots of the different parts of the spine in the American War as 70 per cent. in the cervical, 63.5 per cent. in the dorsal, and 45.5 per cent. in the lumbar regions. Of 54 cases in which there was lesion of the cord, 42 died, and the remaining 12 were discharged with varying degrees of physical disability. Longmore refers to 32 cases, detailed in "The Surgical History of the Crimean Campaign," in which the vertebræ were fractured, 10 being without apparent lesion of the cord, and 22 with lesion; of these, 28 died, and 4, in which the processes only were injured, survived to be invalided.

Symptoms depending on Injury of the Cord.—The symptoms indicating implication of the cord in cases of gunshot of the spine vary, of course, with the region in which the wound occurs, and they differ in no way from those observed in cases of fracture-dislocation met with in civil hospitals and due to other causes; but some reference to them may be made in general terms. When the spinal cord is lacerated or compressed, as the result of gunshot fracture of one or more of the vertebræ, immediate and complete paralysis of all the parts below the seat of injury takes place. The sphincters lose their contractile power, and, after a short interval of retention of urine, the contents of both the bladder and rectum are passed unconsciously. The escape of urine is due to a complete paralysis of the neck of the bladder, permitting its evacuation as it is secreted, and not to the overflow from a distended bladder. Loss of sensation usually, but not invariably, accompanies the loss of motion, but it may not be so complete nor spread over so wide an area as the latter. A line of hyperæsthesia may mark the junction of the normal and

the affected skin surfaces. The temperature of the paralysed parts may be very high immediately after the receipt of the wound, but later it may fall below normal. Reflex action at first is lost, but later becomes exaggerated. Persistent priapism is a common symptom in cases where the injury happens in the upper regions of the cord. Sloughing of the soft parts situated over bony prominences, sometimes referred to as "acute bed-sore," due to trophic changes and interference with nutrition processes, and almost independent of pressure, is a common symptom in these cases. The sloughs sometimes form rapidly, and long before bed-sores properly so called make their appearance. Cystitis and the appearance of ammoniacal urine containing pus and mucus, depending on changes in the bladder and kidneys, sometimes rapidly develop, and sometimes not until after the lapse of weeks or even months; this condition is a very common cause of death in cases of spinal injury.

Concussion of the Cord without fracture of the spinal column may be produced by shell fragments or by small-arm projectiles. In these cases paralysis below the seat of injury may be absolute; but if secondary changes do not take place in the cord, and hæmorrhage within the spinal canal does not occur, recovery may be rapid and complete. The case of an officer wounded at Maiwand, during the last campaign in Afghanistan, is of interest in this connection. The bullet traversed the muscles over the lumbar region from side to side, not implicating bone in its passage; absolute paralysis of both lower extremities occurred immediately on receipt of the injury, and continued for about a week, when it began to diminish and soon completely disappeared.

All degrees of direct injury to the cord may be produced by bullets, from slight compression by depressed fragments of the vertebræ and intra- or extra-dural hæmorrhage, to laceration and complete section. Taking into consideration the physiology of the spinal cord, unilateral injuries should produce motor symptoms on the same side as the lesion, and sensory symptoms on the opposite side.

But cases of this kind, if possible, must be extremely rare. When the cord is directly injured by a bullet, the damage done is usually so extensive that its functions to all the parts below, on both sides of the body, are lost immediately.

Lacerations of the cord in almost any region are extremely fatal injuries. When they occur high up in the cervical region, above the origins of the phrenic nerves, death usually takes place immediately; but even in these cases life may be prolonged for from twelve to twenty-four hours. When situated lower down, and when death does not take place so rapidly, they are still usually fatal, after a more or less prolonged period, from the secondary myelitic changes which supervene, and gradually extend upwards until the functions of organs essential to life are so interfered with that death must result. When the injury is in the dorsal region the prognosis is only better as regards the time during which life may be prolonged, and death in these cases is usually the result of bed-sores, and of the secondary trophic changes produced in the bladder and kidneys. It is only in cases of wounds of the cord in the lumbar region that there is much hope of permanent, though usually very incomplete, recovery. The lower down the wound is, the better is the prognosis; but even in injuries of the lower lumbar vertebræ, partial or complete paraplegia, or great weakness of the lower extremities, may remain for months or years, or even for the remainder of the patient's life. But in these cases also prognosis must be guarded, because of the possibility of the occurrence of secondary ascending myelitic changes, which, if they supervene, are certain to cause death.

During the American War 642 cases of gunshots of the spine were observed, which gave a death-rate of 55.5 per cent. The cases which survived these injuries were almost exclusively those in which the spinous and transverse processes only were fractured; although Otis does refer to some few instances in which the bodies of the vertebræ were injured, which were not fatal. In the American report of the cases where recovery took place, it is nearly

always referred to as being only "more or less complete," the large majority of the patients suffering permanently from paraplegia, or from paresis of the muscles below the site of injury, incontinence of urine, cystitis, and inability to stand erect. Both Longmore[1] and Otis detail cases of gunshot injury of the cord (lumbar region) in which paralysis did not occur, but they are probably the only instances of this kind on record. It is, however, well known that fracture of the lower lumbar vertebræ does not always entail paralysis.

The Causes of Death in gunshots of the spine—are (1) section or laceration of the cord in the higher cervical and dorsal regions, producing interference with the nerve supply of the muscles on which the movements of respiration depend; (2) hæmorrhage in the spinal canal, either within or without the dura mater; (3) spinal meningitis; (4) ascending or descending myelitis; (5) cystitis and degeneration of the kidneys, due to trophic lesions in the urinary organs; (6) exhaustion from "acute" or ordinary pressure bed-sores.

The Treatment of gunshot fractures of the spine should be carried out with all possible precautions directed towards an aseptic condition of the wounds. Suppuration, if the spinal canal has been laid open, is the certain precursor of such fatal complications as spinal meningitis and myelitis, and therefore the employment of the means to avoid conditions in the wounds which produce them deserve very special attention. These have already been frequently referred to.

Fractures of the bodies of the vertebræ are usually accompanied by severe injury to the cord, but operative interference for the purpose of remedying displacement of bone fragments is impossible in these cases. On the other hand, when the posterior bony arch of the spinal canal is fractured, the skin wound may be enlarged to admit of exploration with the finger, and removal of quite detached fragments of the transverse and spinous processes. This is all the more necessary when there are symptoms of

[1] Holmes' "System of Surgery."

compression or of irritation of the cord or its membranes by depressed fragments or by sharp spiculæ of bone, for in these cases elevation or removal of the offending particles of bone is required in order to prevent inflammatory processes in the cord, which must produce a fatal result.

Formal trephining of the spine and laminectomy for gunshots are never required as primary operations, and the procedures above referred to can best be carried out by means of such instruments as elevators, bone forceps, scissors, gouges, &c.—not with the trephine—through an incision of sufficient length in the soft parts over the site of fracture. If the bullet has lodged, it should be removed if its situation can be discovered. The wound should be dressed with iodoform, and the usual gauze and wool applications lightly fastened on with bandages, avoiding compression of the chest and abdomen. Frequent movement of the patient for redressing should be avoided.

The general treatment is similar to that of fracture-dislocation of the spine. The bed on which the patient is placed should not be of the spring-mattress kind; a fracture-bed should be used. The bowels should be attended to, as constipation is almost always a symptom in these cases; and while retention of urine continues, an aseptic soft rubber catheter should be passed three or four times a day. When the urine becomes ammoniacal, and gives any deposit of mucus or pus, the bladder should be washed out twice a day with warm boracic acid solution.

"Acute bed-sores," if there be a tendency to their formation, cannot be avoided, as they are the results of trophic lesions depending on injury to the cord; but the ordinary pressure bed-sores must be guarded against by the usual means. Extension and counter-extension, so frequently found necessary in cases of fracture-dislocation in civil hospitals, are seldom required in gunshots of the spine, because the solution of continuity of the spinal column is seldom complete, and under these circumstances there is no tendency to displacement. If the patient survive and paralysis continue, the advisability of the performance of laminectomy may have to be considered; but

the operation is useless if signs of ascending or descending myelitis be present.

Men with gunshot injuries of the spine are in a condition which precludes transport to hospitals in the rear, and the greatest care is required to avoid doing further damage to these patients when they are being moved to the dressing stations and field hospitals. The men of the stretcher squads of the bearer companies should be made to understand this in connection with men wounded in the back and with paralysis of the limbs, as any rough or careless movement of patients injured in the spine, while being placed upon the stretchers or into the ambulance wagons, may so increase the damage to the cord as to cause rapidly fatal results.

CHAPTER XI

WOUNDS AND INJURIES OF THE CHEST

ABOUT 8 per cent. of all the wounds treated in war hospitals since the Crimean Campaign have been wounds of the chest, while the proportion of those who have succumbed on the battle-field from injuries of this class has varied from 50 per cent. (Koch), to 33 per cent. (Loeffler and Lidell) of those killed in action. More than 20,000 wounds of the chest were tabulated by Otis as having occured during the American War, and gave a death-rate of 27.5 per cent. for all injuries of the chest, including non-penetrating wounds and contusions, as well as those in which the contents of the thorax were implicated. Non-penetrating injuries were fatal in but few instances, mere contusions affording a mortality of 2.2 per cent., and gunshot flesh wounds 1 per cent.

Penetrating gunshot wounds, on the other hand, were extremely grave injuries in the American as in other wars, 62.5 per cent. proving fatal. The fatality of penetrating gunshots of the chest has always been high. In the Crimea the French lost 91.6 per cent. of these cases,[1] and our army 79.2 per cent.;[2] the excessive mortality amongst the French being due, according to Longmore, to the advanced position of their field hospitals, enabling patients to be admitted as "wounded," who, if the hospitals had been a little farther away, must have died on the field or in the entrenchments in consequence of the great severity of their injuries. In the Italian War of 1859–60, 61 per cent. of these cases died.[3] Of nearly 9000 cases noted in the American War, 62.5 per cent. died. MacCormac reports a death-rate of 54.8 per cent. for penetrating wounds of the chest at Sedan during the war of 1870–71, and Fischer 55.8

[1] Chenu. [2] Matthew. [3] Demme.

per cent. at Metz. Otis gives a table showing the death-rates for penetrating wounds of the chest in the different wars, from the campaign in New Zealand in 1863–64 to the Franco-German War in 1870–71, but excluding the war in America, from which an average mortality of 65.2 per cent. may be calculated. These figures, combined with those of the war in America, demonstrate the gravity of gunshot wounds implicating the lungs, vessels, and bony walls of the thoracic cavities, and prove that considerably more than half the cases of this class which reach the field hospitals for treatment eventually die. Indeed, some authorities whose opinions are entitled to respect, believe that all gunshots of the lung substance prove fatal sooner or later.[1]

Sword and bayonet wounds of the chest in warfare are exceptional; 86 such cases occurred amongst the Germans in 1870–71, and out of 20,607 wounds of the chest Otis only records 9 sword and 29 bayonet wounds, with a death-rate of 11.1 per cent. and 33.3 per cent. respectively.

Contusions of the Chest, accompanied by graver symptoms than slight pain and a passing dyspnœa, but without wound of the soft parts or fracture of the bones, are rare. Yet occasionally a large projectile, such as a bullet from a case-shot, or the smooth surface of a large shell fragment, may produce so violent a concussion of the chest wall as to cause rupture of the lungs, heart, or great vessels, and immediate death. Short of this, contusions by missiles of the kind mentioned may cause rupture of the smaller vessels of the lung, or small tears in the visceral pleura, giving rise to severe symptoms of hæmoptysis, pneumo-thorax, hæmothorax, and, later, to those of traumatic pleurisy and pneumonia. When the force of the contusion of the lung ruptures some of the air cells on the surface, air may escape under the visceral pleura and make its way to the root of the neck, giving rise to subcutaneous emphysema in that situation. The other immediate symptoms which may accompany those just mentioned, are a

[1] Drs. Matthew and Fraser; Crimean War.

more or less marked degree of collapse, rapid, weak pulse, shallow, irregular breathing, and dyspnœa.

The Treatment of these cases should be directed towards recovering the patient from his condition of collapse by the use of stimulants and warmth; hot water and alcohol by the mouth and rectum, and ether subcutaneously; friction to the surface, hot bottles to the feet and legs, and artificial respiration if required. The side on which the injury has been received should be strapped, to diminish pain, and to keep the part as much at rest as possible. If the breathing is being much interfered with from the occurrence of pneumothorax or hæmothorax, or, as is more probable, from a combination of these conditions, the case must be treated on the general principles applicable to it, viz., the removal of the air and blood from the pleural cavity by the aspirator.

Non-Penetrating Gunshot Wounds of the chest are by no means a fatal class of injury, but they often heal slowly, and are prone to be followed by sinuses through the soft parts, in consequence of the impossibility of securing, in this situation, the rest and immobility so necessary for rapid repair of wounded tissues. The projectile is frequently found lodged in the chest walls, and, although the lung is not directly injured, hæmoptysis is a common sign in these cases. In future wars, injuries of this kind will be less often met with, except where the bullet strikes obliquely or tangentially: the modern rifle-bullet will fail to penetrate the chest only at extremely long ranges, certainly not under 2500 yards, or even more. Fractures of any portion of the bony walls of the chest may be met with in cases of non-penetrating wounds, but do not add very much to their gravity, except, perhaps, as indicating that with this complication asepsis is all the more important.

The Treatment should be carried out on the usual strictly antiseptic lines. Foreign bodies, such as the bullet, pieces of clothing or accoutrements, &c., must be removed; and if this has been done or attempted, or if the wound has been explored, the bullet track should be irrigated. Drainage need not be employed even if the bullet

has passed for some distance between the bones and the skin; on the contrary, the sides of the bullet track should be approximated by means of a firm pad of gauze laid over it to prevent their separation by effused blood, and the formation of sinuses through the muscles. Hæmorrhage must be controlled by ligature of the bleeding points in the wound, and dry gauze and wool dressings applied under a wide bandage. If pain be severe from the respiratory movements, the side may be strapped to keep it at rest, and if hæmoptysis occur, it is best treated by the application of cold, the use of ergotine, and perhaps of calcium chloride as recommended by Professor A. E. Wright, M.D.

Penetrating Wounds of the chest form a very serious and fatal class of injuries, nearly half the number of those killed in action being wounded in this region, while the mortality amongst those admitted to the field hospitals has hitherto ranked only second to that following gunshots of the hip joint. They may be complicated by fractures of the upper half of the humerus or of the shoulder joint, as well as of the clavicle, the scapula, the ribs, sternum, and dorsal spine. Together with these injuries there may be wound of the subclavian vessels, of the thoracic duct, the large vessels of the chest, the heart, the œsophagus, the diaphragm —in fact, of any portion of the vital and important structures contained within the thoracic walls. Many of these complications are of such a nature as to prove rapidly fatal, usually from hæmorrhage from the large vessels or heart, or into the lung substance, producing suffocation, or into one or both pleural cavities, causing such interference with the respiration that life cannot be sustained. The difficulties with which the surgeon has to contend in those cases which survive to come under treatment are, for the most part, fractures of the bony walls of the chest, gunshots of the lung substance, hæmorrhage from the lungs and from the vessels of the chest walls, and the secondary complications which may arise from these injuries.

The ratios of mortality given above, refer, of course, to injuries following wounds by smooth-bore balls and

rifle-bullets of large calibre. Wounds of the lung, by the modern hard-mantled projectile, will probably be of a distinctly more favourable character. I am unable to refer to any statistics on this matter, because none have been published so far; but it would seem to be a well-authenticated fact that in the late Chilian War, when for the first time both sides used modern small-bore rifles, wounds of the lung were less fatal, and healed far more rapidly than do similar injuries by the larger bullets. In the German report already referred to in an early chapter, von Coler, excluding cases of suicide, gives the death-rate of wounds of the lung, in his experience, as 12.5 per cent.; and Fischer's statistics[1] put the mortality at 44.4 per cent. According to Coler, Habart, Bruns, and others, when the large vessels, especially those at the root of the lung, are not wounded, these cases offer a favourable prognosis. The bullet track through the lung is smooth and narrow, with but little destruction of lung substance in its vicinity, and splinters of bone are but seldom driven in. Neudörfer, writing in 1867, said that all penetrating wounds of the chest were complicated by fracture, and no doubt fracture of the ribs, &c., did occur in the large majority of wounds produced by the old bullets. But the present bullet of small diameter can readily pass through an intercostal space without touching bone, and this fact, together with the narrowness of its track through the lung, accounts for the lower death-rate following penetration of the chest by the new projectile.

Fractures of the bones of the chest greatly complicate these cases, especially when they take place at the entrance side; splinters of bone are driven into the lung for considerable distances, and remain there, acting as foreign bodies of the most irritating kinds, setting up and increasing the traumatic pneumonia. Whereas fracture of a rib at the exit side is of comparatively small importance, and adds but little to the difficulties of the case, the bone splinters being driven outwards into the soft parts of the chest walls.

"Contour" bullet wounds, where the missile travels

[1] "The Surgery of War," vol. ii.

partly round the body between the ribs and the skin, escaping at another opening, were fairly common with the old bullets, and especially with the round bullet; but injuries of this class are unlikely to be observed with the small-bore bullet travelling at any rate of velocity. Coler reports that none occurred in his series of experiments. Lodgment of the projectile, too, which was formerly not at all a rare accident, will never be seen in men wounded by the smaller bullets, except at extremely long ranges.

Recovery follows bullet wounds of the lung in a certain proportion of cases, and some instances are reported of recovery even after perforation of both lungs. Otis remarks apropos to cases of this kind seen in the American War, that "the probabilities are remote of anything like a permanent restoration to even a partial degree of good health after such an injury." Fischer reports a case in the Franco-German War which survived after three bullet wounds of the right chest.

Diagnosis of Wound of the Lung.—The symptoms to which wounds of the lungs may give rise immediately on receipt of the injury are those of shock, difficulty of breathing, more or less collapse, cough, hæmoptysis, hæmorrhage, pneumothorax, and the passage of air to and from the pleural cavity through the orifice in the walls of the chest. The hæmorrhage may be principally external from laceration of the vessels in the parietes, or internal from wound of the same vessels or of those of the lung substance. These are the signs laid down in text-books to enable the surgeon to form an opinion as to the existence or otherwise of wound of the lung in cases of penetrating wounds of the chest. But, notwithstanding the accuracy with which these symptoms are detailed by authors, it frequently happens that, although it may be quite evident that the chest cavity has been opened by a bullet in a given case, it may not be easy to decide whether or not the lung has been wounded. In the immense majority of penetrating wounds the contents of the thorax will be implicated in the injury, but in very exceptional cases they

may escape. An inference of wound of a particular portion of the parts within the chest may, no doubt, be drawn from the situation of the wounds; but it is well known that each of the signs of wounded lung—shock, dyspnœa, hæmoptysis, and the escape of blood and air by the wound—formerly thought to be characteristic, may be present without this accident having occurred. Indeed, the symptoms of shock and dyspnœa may be as well marked in cases of contusion of the chest where there is neither fracture of the ribs or sternum, nor wound of the soft parts, as they are in cases where the lung is wounded, and hæmoptysis may be present.

Spitting of blood was formerly thought to be a fairly certain sign of wound of the lung, but hæmoptysis so frequently results from non-penetrating injuries of the chest walls that this is now admitted to be erroneous. Except in conjunction with other symptoms, it is of but little value as a sign of lung wound. In the Crimea, Fraser reports that out of 9 fatal cases of gunshot of the lung, only 1 had hæmoptysis, and that of 7 fatal cases in which the lung had escaped injury, 2 had hæmoptysis. Matthew states that most of the cases in the Crimea had hæmoptysis, but not nearly all. Regarding the experience in this connection gained during the American War, Otis states that it only occurred in 492 out of 8715 penetrating wounds of the chest, and that "it was absent in the larger number of undoubted shot wounds of the lung, of which specimens are preserved in the Army Medical Museum." Since then, hæmoptysis may occur without wound of the lung, and wound of the lung without hæmoptysis, it is evident that the presence or absence of this sign is not to be depended on in forming a diagnosis. Blood welling up into the mouth again and again after a chest wound is a much more certain sign of lung injury; while ordinary hæmoptysis, or blood-stained sputum, does not of itself prove that the lung has been penetrated.

The passage of air, or of blood mixed with air, in and out through the perforation in the parietes — "traumatopnœa," as it is called—is absolutely valueless as a sign

of lung injury; or, to speak more accurately, the existence of this symptom is not conclusive evidence that the lung has been wounded. It occurs in cases where there is no lung wound; when, for instance, an opening is made into the chest and any degree of collapse of the lung takes place; when, in fact, there is a cavity within the chest in direct communication with the outer air. Under these circumstances air and blood will be forced in and out with a loud bubbling sound, precisely similar to what occurs when the lung is wounded, except that in the latter case the air comes from the lung, while in the former it has first been drawn in from the outside air. When an empyema has been opened, and some of the pus has flowed out, air is drawn in and expelled with each movement of respiration; and even when an abscess of the liver has been evacuated, the same thing occurs. In fact, when any cavity communicating with the outer air exists within the chest, expansion of the chest walls during inspiration must fill it with air, while expiration empties it, thus producing an appearance of traumatopnœa, though no air may be escaping from the surface of the lung, the condition which this term is really meant to define. Moreover, true traumatopnœa is not a frequent symptom when the lung is wounded; it is noted only in 49 cases out of the 8715 penetrating gunshots of the chest recorded by Otis.

On what, then, if the commonly recognised symptoms of lung wound are untrustworthy, are we to base a diagnosis? Principally on *the situation* of a penetrating wound of the chest, and the direction of the bullet track between the entrance and exit apertures, combined with the presence of the symptoms already referred to, or of some of them. The limits of the pleural cavity on the right side are from a little above the clavicle to the sixth interspace in front, the ninth rib in the mid-axillary line, and to the twelfth rib behind; on the left side they extend a little lower in front and in the axillary line than on the right side. A penetrating wound within the area thus mapped out may be considered to include penetration of the pleura, and probably of the lung, and especially when its exist-

ence is found to be in conjunction with the presence of some or all of the symptoms above mentioned.

The Treatment of Penetrating Wounds of the Chest.—The treatment of these injuries, when they are unaccompanied by any of the grave complications to be referred to further on, is very simple. The wounds and the surrounding skin surface should be rendered aseptic by the usual means. If the bones of the thoracic walls have been fractured, the wound on the entrance side should be explored with the finger for the discovery and removal of loose fragments and sharp spiculæ of bone which may have been forced inwards, and may be irritating and lacerating the pleura and lung, and for this purpose the skin wound may require to be enlarged. Loose pieces of bone should also be removed if found at the exit wound. The apertures should then be dusted with iodoform, and closed with the usual dry gauze and wool dressings under a wide bandage or binder.

Antiseptic precautions are no less important in cases of gunshot of the chest than they are in other wounds, and failure to employ them effectively are no less deleterious. All the very fatal secondary complications which follow on wounds of the lungs and pleura are due to infection of the bullet track, and every means should be taken to prevent the occurrence of this accident.

Hermetically Sealing is a method of treatment of penetrating wounds of the chest which was recommended by Dr. Howard, U. S. Army, and largely tried during the American War. It is carried out by paring away the contused edges of the apertures in the chest wall, and closing them with wire sutures: layers of absorbent wool, or of gauze, wet with collodion, are then laid on the wound and allowed to dry, as many layers being applied as may be considered necessary to completely seal the opening, a pad of dry wool, and a bandage over all, completing this treatment. In one list of 69 cases so treated, 27 recoveries are recorded, or a mortality of 60.8 per cent. But Otis himself eliminates 24 of them for one reason or another—inaccuracy of diagnosis of penetration, absence of information as to

the final result, or evidence that the patient's condition was far from satisfactory—and he sums up by saying that "only three are authenticated cases of complete and permanent recovery under this treatment"; adding that "it is probable that the routine application of the plan has not been unattended by disastrous results." MacCormac[1] is no less decided in his opinion of this method: "I am sure," he writes, "that the plan so unhesitatingly denounced in the report of the Surgeon-General of the United States Army is a bad one, and worthy of the censure with which it is there stigmatised." Hermetically sealing may possibly be a suitable method to employ in those exceptional cases of penetrating gunshots of the chest unaccompanied by such complications as pneumothorax and hæmothorax, when, indeed, any aseptic application suffices; but to permanently close the superficial wounds, while the pleural cavity is filled with air and blood, and while hæmorrhage is still going on, is to court disaster by procedures which are contrary to the science of surgery. This method of treatment has been known as the "American plan" since the war of the Rebellion, but it was by no means new when it was recommended by the American surgeon. Paré, Larrey, La Motte, and many surgeons advised and practised it in the last century. Longmore tells us that Von Graefe, of Berlin, so treated a case in 1827. Closure of the wound may, under certain circumstances, as will appear later, be the only thing left to do; but primary sealing of the openings in the skin and soft parts "has failed," as Otis remarks "to promote cicatrisation of the torn track out of sight," and only tends to mask the evidences of the grave complications which are present within the patient's chest threatening a rapidly fatal issue.

The Complications of penetrating wounds of the chest which may occur immediately on receipt of the injury, are hæmorrhage, pneumothorax, emphysema, and fracture of the bones of the chest wall; those which may supervene at a later period are pneumonia, pleurisy, and empyema.

Hæmorrhage is the most fatal complication which can

[1] *Op. cit.*, p. 70.

accompany these cases. When it arises from wound of the large vessels in immediate relationship with the heart, death is, of course, instantaneous; but even when only the internal mammary or intercostals, or the larger vessels of the lung itself, are wounded, the hæmorrhage which occurs may be of a most serious nature. The large majority of deaths which take place during the first three or four days after the receipt of chest wounds are due to this complication. When it proceeds from the internal mammary artery or from the intercostals, the blood may escape outwards through the wounds, or it may pass into the pleural cavity, producing hæmothorax, the lung collapsing to a greater or less extent as the blood accumulates. Hæmothorax, more or less marked in degree, must always follow upon any wound of the lung substance; but when the root of the lung, where the vessels are large, is implicated in the injury, this complication becomes of a most dangerous nature, and it is but little amenable to treatment.

In the treatment of wounds of the arteries in the chest walls, there are two methods to be employed—ligature of both ends of the vessel in the wound, and pressure by Desault's plan, the latter only to be used when the former is found to be impracticable. An intercostal may be ligatured either by passing a thread round the rib above it, or by incising the periosteum longitudinally and separating it from the end of the fractured rib with a raspatory, when the artery will be raised with the membrane and the ligature can be readily applied. Each end of the torn artery must be treated by whichever method is employed, and whether the rib be fractured or not.

Hæmorrhage from the vessels about the scapula, which are large and give rise to profuse bleeding, must, if possible, be treated by direct ligature of both ends in the wound. This is often a difficult proceeding to carry out, on account of the depth at which some of them are placed, and if it cannot be done, pressure by a graduated gauze compress must be substituted.

Hæmorrhage from an internal mammary is a very serious complication, in consequence of the great difficulty of

applying a ligature to this vessel in some parts of its course. Nélaton observes that hæmorrhage from a wound near the margin of the sternum, and between the first and seventh ribs, may be suspected of coming from the internal mammary, and that the lower down on the sternum, that is the nearer the wound is to the seventh rib, the greater is the difficulty in tying the vessel. In the first three interspaces the vessel may be ligatured with comparative ease, but below that it may be necessary to remove the cartilage of the rib implicated in or nearest to the wound.

If ligature be impracticable, pressure by Desault's plan must be used: the centre of a small square of aseptic gauze is to be laid over the wound, and pushed into the pleural cavity with the fingers; the bag thus produced is stuffed with a sufficiency of gauze, the four corners of thc square of gauze are lifted off the chest, and pulled upon until the pad within is made to compress the ends of the bleeding vessel against the sternum or ribs; the neck of the gauze bag should then be tied close to the chest wall, and a large safety-pin passed through it, to keep up the pressure, and prevent its slipping back into the pleural cavity. This method of compression is applicable to any of the deeper arteries of the thoracic walls. It cannot be too strongly insisted upon, that hæmorrhage from these vessels is a most dangerous complication, that it is unlikely to cease spontaneously, and that therefore persistent efforts must be made, after enlargement of the skin wound, to control it by either of the mechanical means just referred to.

Hæmothorax.—The accumulation of blood within the pleura may result either from laceration of the vessels in the parietes or of those in the lung substance. When it proceeds from the large arterial and venous trunks in or near the root of the lung, the hæmorrhage is of far greater importance than it is in the former class of cases, in consequence of the impossibility of direct treatment of the severed vessels. In a large number of cases where the bullet traverses the root of the lung or its vicinity, the patients die immediately from loss of blood or suffocation, the functions of the wounded lung being interfered with

by its partial or complete collapse, and those of the sound one by the passage of blood into it through the large bronchi. When, however, vessels in the lung of less magnitude are implicated, the hæmorrhage may be less free, or it may cease spontaneously from the formation of clots or in consequence of compression due to collapse of the lung, and thus patients in whom this formidable complication exists, or is in process of formation, survive to reach the field hospitals. Hæmothorax is almost invariably combined with pneumothorax, from the entrance of air into the pleura, either from the wounded lung or through the opening in the chest wall. It usually occurs immediately on receipt of the wound, but it occasionally happens many days later as a secondary complication.

The signs of hæmothorax are those indicative of great loss of blood, combined with extreme dyspnœa and the symptoms of fluid in the pleural cavity. The dulness on percussion, the absence of the vesicular murmur, and the loss of vocal fremitus are first perceived low down behind, and then, as the lung collapses, extend upwards and to the front, until eventually they may perhaps extend all over the area formerly occupied by the lung in which the wound has happened. Blood mixed with air is coughed out through the wound, and is expelled by the respiratory movements.

In the Treatment of hæmorrhage from the lung, if profuse, the surgeon finds himself in a very helpless position, the only satisfactory method of dealing with a wounded vessel being out of the question. A minor degree of syncope, if producing cessation of the loss of blood, should not be interfered with by the usual means of counteracting it. If, on the other hand, it be so marked as to threaten life, it must be combated at all risks, even that of renewing a hæmorrhage which it may have interrupted. Ether (30–40 m.) should be injected under the skin; stimulants should be given by the mouth and rectum; warmth applied to the surface by hot blankets and hot bottles; friction used to the limbs, and the patient kept as quiet as possible with his head low. This treatment should not be continued any

longer than is absolutely necessary, and should be desisted from on the first signs of reaction showing themselves, lest a recurrence of the bleeding, which may have ceased, be provoked.

If there be but little or no sign of syncope, and the hæmorrhage be still going on, all the surgeon's attention must be devoted to controlling it. Cold by means of ice-bags may be applied to the wounded side, and eating ice may be useful. Absolute quiet is advisable; but this may be difficult to attain, because patients who have suffered great loss of blood are usually restless, and inclined to throw themselves about in bed, fighting, as it were, for breath and life itself. Drugs are of but little avail, and the only ones likely to do good are opium, ergòtine subcutaneously, and chloride of calcium.

But the question regarding which surgeons differ in opinion, is that of the local treatment of the wound—should it be closed, by sutures or otherwise, or should it be left open? Guthrie recommended that it should be closed; the blood then accummulating in the pleural cavity compresses the lung, and thus permits of closure of the severed vessels, and their sealing by clots.

Paré, Larrey, and Legouest, as well as many other English, American, and foreign military surgeons, have also advised closing the superficial wound, at least at first. The urgent dyspnœa is often greatly relieved by this procedure, and the hæmorrhage is sometimes controlled by the compression which is set up. But this satisfactory result is not always brought about. On the contrary, all the symptoms may soon become aggravated by the continuance of the effusion, and death again be threatened from interference with the respiration in the sound lung by the tension set up on the injured side. Under these circumstances there is no alternative but to reopen the wound, and, if necessary, enlarge it for the removal of the clots. Ice-cold water may be injected into the pleural cavity, as recommended by Delorme; but if the bleeding continues, the wound must be again closed, cold applied, and the patient laid upon the wounded side — "thus persevering,"

as Otis remarks, "opening, closing the wound, hoping to gain time, and stave off the most pressing danger."

If this be all the surgeon is capable of doing—and I am unable to suggest more efficacious methods—when confronted with a severe case of hæmothorax, it will be evident how powerless he is, and how ineffectual is his science to save life in these cases.

In former times venesection was almost invariably practised for hæmorrhage of this class; but the treatment by general blood-letting need only be mentioned here in order to state that, since Fraser in 1859 drew attention to its fatal results, it has been condemned on all sides, as illogical in theory, and disastrous in its effects. If, with the wound closed, the hæmorrhage should cease, the blood must be removed after four or five days, by reopening the wound, or through a more suitably placed incision, and thorough disinfection of the pleural cavity carried out; otherwise a septic empyema is certain to result.

Hæmothorax and pneumo-hæmothorax may occur in cases of contusion of the chest with or without fracture of the ribs or laceration of the soft parts, by the production of lacerations in the lung due merely to the violence of the concussion or to spiculæ of bone being driven inwards. The treatment of the complication when due to these causes differs in no way from that suitable in cases of penetrating gunshots, except that it may be necessary to make an opening for the evacuation of the effused blood, if life be in danger from the effects of compression of the lungs. These cases are not so fatal in their results as the others, because the lacerated vessels are usually on the surface, and probably of smaller dimensions.

Emphysema.—Formerly subcutaneous emphysema was looked upon as one of the valuable signs of wound of the lung, but the experiences of the wars of the last sixty or seventy years have led surgeons to modify their views in this connection. Larrey considered that the majority of penetrating wounds of the lung gave rise to emphysema, and similar opinions were held by many other surgeons of his and later times. It was, moreover, thought to be a

complication of wound of the chest of great gravity. In the later wars the symptom has been but seldom observed in cases of lung wound, and when it has occurred the danger to the patients has been but slightly, if at all, increased. During the American War emphysema was noted in only 38 out of the 8715 cases of penetration of the chest, and Neudörfer is of opinion that 0.5 per cent. represents the ratio of its occurrence.

Emphysema may result in cases of non-penetrating wounds and contusions, as well as in those in which the chest is opened. In the former case a sub-pleural laceration of the lung may be produced by the concussion, and air escape from the ruptured vesicles into the interalveolar connective tissue; it then passes, in the direction of least resistance, towards the root of the lung, into the mediastina, and thence, by way of the loose tissues around the large vessels and œsophagus, into the neck, where it appears as subcutaneous emphysema, and may extend more or less over the body. This accident occurs in but rare and exceptional cases, and the infiltration of the tissues with air hardly ever spreads to any great extent.

Then again, when the ribs are fractured without external wound, and spiculæ of bone lacerate the visceral pleura and lung, producing pneumothorax, the expiratory movements of the chest walls may force the air from the pleural cavity through the wound in the parietal pleura, into the muscular and connective tissues, causing emphysema, which may be, and usually is, confined to the parts over the site of injury.

When emphysema occurs with penetrating wounds of the chest, it is usually in conjunction with valvular wounds of the soft parts caused by bullets or by stabbing weapons entering the chest obliquely and wounding the lung. Pneumothorax then forms; the air passes into the superficial tissues, and spreads there, not escaping by the skin wound, which does not correspond to that in the deeper structures. With extensive openings or direct penetrations of the chest, emphysema is unlikely to occur, because the air finds a free outlet. The symptom may result either from thrusts by

side-arms or from gunshots, and it seldom extends over a wide area, though occasionally it may do so.

When a bullet traverses the pleural cavity, and lodges in the chest wall opposite to the side of entrance, emphysema may occur at the latter situation alone, or it may, under these circumstances, be present on both sides.

The Treatment of emphysema, when anything more than simple confinement of the injured side by strapping from the spine to the sternum is required, consists in making multiple small incisions through the skin to facilitate the escape of the air, and this should always be done aseptically. Suppuration in the emphysematous tissues is unlikely to take place, because the air comes from the superficial parts of the lung, and has been thoroughly filtered of micro-organisms by its passage through the vesicles and air-tubes; but when incisions must be made, precautions against their contamination are necessary.

Pneumothorax.—This complication may supervene on non-penetrating injuries of the chest, when the lung and visceral pleura are torn from concussion, or by spiculæ of fractured bones being forced inwards, and also on gunshots or other injuries which open the chest cavity. When the pleural cavity is penetrated it does not always follow, as one might suppose, that collapse of the lung takes place immediately, unless the wound be large, or be placed over one of the free borders of the lung or of one of its lobes. Pneumothorax can only form in proportion to the amount of collapse which occurs; it therefore follows that if the one condition is not well marked, neither can the other be so. When the lung collapses in consequence of an opening in the chest wall through which air can enter and escape freely, pneumothorax, in the strict meaning of the term, no doubt is produced; but the shrinking of the lung ceases when the air pressure within it and in the pleura becomes equalised, and these are not the cases where the urgent dyspnœa and dangers to life occur from this condition. When, on the other hand, wound of the lung and visceral pleura is found in conjunction with a wound in the chest wall which is small, or valvular, and tends to prevent the

exit of the air, the lung is gradually, but forcibly, compressed against the spine, and a high degree of tension is set up within the chest by the air which escapes from the laceration in the visceral pleura at each expiration, and cannot find exit from the pleural cavity. These are the cases where the difficulty of breathing becomes extreme, and life is in imminent danger from pressure on the sound lung and on the heart; but fortunately it seldom happens that these extreme degrees of pneumothorax are reached, the reason being that the openings in the parietes are usually sufficiently free to prevent their occurrence. Amongst the large number of cases of chest injury seen in the American War, only half-a-dozen such cases were reported. Pneumothorax is always combined with more or less hæmothorax as well.

The symptoms of the condition do not require any detailed description; they are, of course, the usual percussion and auscultation signs of air in the chest, combined with those of fluid in the lower situations, which latter will be more or less marked as the amount of effused blood is great or small.

The Treatment of the milder forms of pneumothorax is included in that of the wound in the chest wall. If from closure of the wound, or from the nature of the case, the dyspnœa and other symptoms of pressure become urgent, aspiration must be performed, and perhaps repeated, through a good-sized needle. If this prove insufficient, or if the symptoms return, the wound must be enlarged, or a fresh incision may be made in a position more suitable for drainage.

Pleurisy and Pneumonia.—A certain amount of pleurisy and pneumonia must necessarily supervene on wounds of the pleura and lung; but in the American report, out of the very large number of penetrations of the chest therein detailed, pleurisy is referred to as a prominent complication in only 94 instances, 52 of which proved fatal. Severe or general traumatic pleurisy was not, therefore, a common occurrence as an acute condition. But later on in the course of the treatment of these cases, pleuritis ending in

empyema is almost certain to result if infection of the wound takes place.

In the same manner pneumonia must occur along the track of a bullet through the lung. But, besides this amount of inflammation, a more general traumatic pneumonia is referred to in Mr. Otis's report as being more frequently observed than was a general traumatic pleurisy; but, as a rule, both of these complications are restricted to the immediate vicinity of the wounds in the lung and pleura. The conditions generally understood by the terms "pleurisy" and "pneumonia" are most rare as grave complications of penetrating wounds of the chest. Dr. Fraser, writing of the Crimean experiences, and Klebs and Socin, writing of the war of 1870–71, state that these complications are exceptional; and Otis, forming his opinion on the vast experience of the American War, agrees with these authorities.

The signs of these diseases, when due to gunshots, are similar to those observed in ordinary cases, modified by the other conditions which accompany them, such as blood and air in the chest, and partial or complete collapse of the lung, which interfere with the detection of friction sounds and crepitations. The sputum may be blood-stained, but this is due rather to laceration of air vesicles and bronchial tubes than to exudation from hyperæmia. The temperature is no higher than might be expected from the existence of the wound, unless septic changes are taking place in the lung or pleura.

The Treatment of these cases should be carried out on the ordinary principles applicable to acute pleurisy and pneumonia, except that advantage should be taken of the presence of the opening in the chest to maintain free drainage by tubes.

Empyema. — Suppuration within the pleural cavity, when only the superficial air vesicles and smaller bronchial tubes are wounded, is not likely to take place from infection through the lung. But when lodgment of the bullet, or pieces of clothing, or other foreign matter occurs, combined with the entrance of air from without, and the pos-

sible necessity of frequent dressing of the wound, contamination of the pleural cavity is likely to result. The lung and pleura are peculiarly susceptible to suppurative inflammation from the lodgment of foreign bodies of any kind, and the effused blood within the chest forms a most suitable culture medium for the growth of micro-organisms. When, therefore, any infective matter is carried in with the bullet or fragments of clothes, or when it gains admission by means of unclean instruments or fingers, it finds prepared for it all the conditions suitable for its rapid development and growth, and for the production of the infective processes due to its presence. Septic empyema is therefore a common secondary complication of penetrating wounds of the chest.

When empyema is suspected, the diagnosis should be made certain by the use of the aspirator, and if confirmed, it should be treated by incision a little behind the mid-axillary line, the introduction of two large drainage tubes, and daily irrigation of the pleural cavity by a warm antiseptic solution. Cases of sudden death following irrigation of the pleura are on record; but with the precaution to have a free outlet for the fluid, this accident need not be feared. Setting up a condition of tension within the chest is the source of danger, but this is impossible if two drainage tubes be used. I have constantly irrigated empyemata from which the discharges have been foul and septic—and nearly all the cases of empyema from gunshot are of this nature—with none but good effect.

Abscess of the Lung.—This complication very commonly results from the lodgment of foreign bodies in the lung, especially fragments of the clothing and of the bony walls of the chest. Usually the cavity is small and localised, but the contents of these abscesses are usually so septic that occasionally a more general infection takes place; the suppuration spreads through a large area of the lung, and this condition usually proves fatal. Foreign bodies of the kind mentioned, or pieces of the bullet, are frequently coughed up after remaining lodged in the lung for months and giving rise to severe constitutional symptoms, the pa-

tient then rapidly recovering; or the abscess containing them may point towards the original wound, or at another part of the chest wall, when they may be expelled or removed by the incision made for the treatment of the complaint.

Treatment.—The treatment of an abscess of the lung due to gunshot should be directed towards the support of the patient's strength by diet, and stimulants if necessary, the evacuation of the contents, and especially the removal of the offending body. If the wound be still open, it should be enlarged, and explored with a trocar; if found by these means, the abscess should be incised and drained in the usual way, a piece of one or more ribs being removed if this operation seems to be indicated. If it point at another part of the chest, the same line of treatment is to be adopted. If no sign of pointing shows itself, but the percussion and auscultation sounds indicate its position sufficiently clearly, and this be considered to be within reach, an operation on the principles above mentioned should be performed. Irrigation of these abscess cavities should not be performed, but a little iodoform emulsion may be passed into them from a small glass syringe, as this may tend to lessen the very septic condition of their contents. When an abscess of the lung has been found and opened, search should be made with the finger and with suitable forceps for the foreign body to which its formation was probably due, but procedures of this kind must be carried out with great gentleness and care.

The Lodgment of Bullets in the Chest. — A bullet may remain fixed in the soft parts or in the bones of the thorax: it may lodge in the lung substance or in the pleural cavity; or it may perforate the chest and lodge in the parietes on the opposite side, beneath the skin or under the scapula. The spine is also a common situation for the lodgment of missiles which have traversed the chest.

The question of the propriety of exploring in these cases, and of operating for the removal of the projectiles, has given rise to much difference of opinion amongst military surgeons, some authorities advocating a systematic

search for the bullets in all cases, and others, while admitting the advisability of their removal if visible in the wounds, declaring that all exploration for the detection of bullets not so situated is improper, and tends to endanger the patients' chances of recovery. But the advantages to be derived from the extraction of lodged bullets are very important, and the relief, both mental and physical, to be obtained by the patients from their removal, will warrant the surgeon in employing the necessary procedures for this purpose, though care and great gentleness are required in their execution, lest further damage be caused and hæmorrhage be provoked. Bullets, no doubt, do sometimes become encysted, and symptoms from their presence cease to be apparent or become unimportant; but these are exceptional cases. As a rule, bullets lodged within the chest continue to produce great local irritation, leading to abscess of the lung and empyema, until coughed up or extracted. In the American War, lodgment of missiles beneath the scapula gave rise in many cases to collections of pus and dangerous secondary hæmorrhage. For these reasons foreign bodies should be removed if possible.

If the projectile be discovered under the skin on the side opposite the entrance wound, an incision should be made immediately for its removal. If the direction of the track leads to the suspicion of lodgment under the scapula, but there is no evidence of the precise situation of the bullet, no operation should be undertaken immediately; time will probably bring forth signs which will change suspicion into certainty, and the removal can then be proceeded with. When the bullet has lodged in the lung, and collapse has not occurred, exploration with the finger or a narrow forceps may lead to its discovery and extraction; but if the lung has collapsed, it will hardly be possible to do anything for its removal until some days after the receipt of the wound. At first the surgeon's attention will be so fully occupied in attempting to prevent death from hæmorrhage and pneumothorax, that no opportunity for exploring for the bullet can present itself; and, as the opening in the shrunken lung will no longer correspond and

be in relation with that in the chest wall, it will be impossible to reach and explore that portion of the track in which lodgment has occurred. A bullet lying loose in the pleural cavity usually makes its way to the upper surface of the diaphragm, and close to the spine, where it cannot be immediately searched for; but it may probably be reached and extracted during the subsequent treatment of the case.

As already stated, lodgment of small-bore bullets will not occur except at extremely long ranges, and therefore this accident will be comparatively rare in civilised warfare, while it may still be common when fighting against enemies using the old spherical projectiles.

Wounds of the Heart and Great Vessels.

When the heart or great thoracic vessels are directly wounded and laid open, either by side-arms or by gunshots, death almost invariably takes place within a few moments; and although there are some cases on record where this did not occur, these are only of interest as surgical curiosities, for no method of treatment is likely to be of permanent service towards their cure.

The heart and pericardium, and possibly the large vessels, are liable to undergo laceration from contusions from large projectiles or their fragments without external wounds of the chest walls or fractures of the bones; these cases also are rapidly followed by a fatal issue.

The pericardium may be wounded either by bullets or by thrusts from side-arms without simultaneous injury to the heart. In these cases, if the heart's action be not so interfered with by hæmorrhage within the serous sac as to stop its movement by compression, recovery may take place. The great danger is the supervention of pericarditis, and when this happens, death is usually the result. Recovery may also take place in cases of wound of the heart itself when the bullet or weapon traverses the muscle obliquely, not opening any of the heart cavities; but wound of the coronary artery in cases of this kind is usually fatal. Delorme quotes the histories by many authors of cases in

which the heart or pericardium had been wounded, where the patients had survived the injury for months or even years; the real facts of the cases only being discovered on post-mortem examination when death had occurred from other causes. An instance of this kind, and one of considerable interest, is given in the Army Medical Department Report for 1873, vol. xv., the salient points of which are

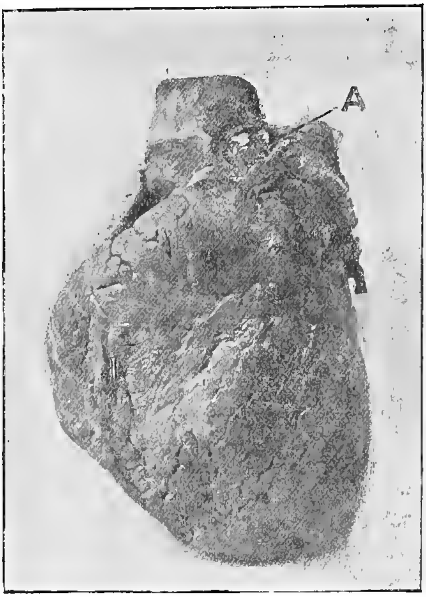


FIG. 75.

Bullet (A) encysted between origins of aorta and pulmonary artery for eleven years.—*Netley Museum.*

as follows: Captain B., of the Royal Navy, was admitted on board the hospital ship *Victor Emanuel* on the West Coast, during the Ashanti War of 1873, for African fever, and died in four days. At the post-mortem a round leaden bullet, half an inch in diameter, was found encysted in connection with the pericardium above the right ventricle, between the origins of the pulmonary artery and the aorta (fig. 75). Captain B. had been wounded in the chest at Taranaki, New Zealand, in the war of 1863–65, and, by a

curious coincidence, Staff-Surgeon Lawrenson, R.N., who had treated him for his wound during the New Zealand War, was also on board the *Victor Emanuel* when he died. Dr. Lawrenson informed the medical officers of the hospital ship that the symptoms produced by the bullet at the time were so slight that penetration of the chest was considered doubtful. This case is referred to by Longmore in his article on gunshots in "Holmes' System of Surgery," and the specimen, with the bullet still in place, is preserved in the Museum at Netley.

The symptoms observed in these cases, when the patients survive long enough to reach the field hospitals, are turbulent, rapid, and irregular action of the heart, dyspnœa, pallor of the surface, and extreme shock. Wounds of the large vessels seldom come under treatment; but when the heart is traversed obliquely, no cavity being opened, and when the hæmorrhage into the pericardium is not of such severity as to cause stoppage of the heart's action, the patients may live for some hours or days, to die eventually of pericarditis or myocarditis.

The Treatment of wounds of the pericardium and of the heart must be directed towards keeping the orifice in the chest wall aseptic, in order to ward off, if possible, the occurrence of suppurative pericarditis and myocarditis, which are usually the secondary causes of death in those cases in which it does not take place immediately from hæmorrhage and shock. They are not amenable to the usual methods of surgical treatment. The skin and wound should be disinfected, iodoform dusted on, and dry gauze and wool dressings applied. If, during the early periods of the case, there be evidence of interference with the heart's action from an effusion of blood into the pericardium, the question of the evacuation of the fluid by operation may have to be considered. Cases of this kind have recovered, but usually they are hardly such as afford any expectation of a satisfactory result. Enlarging the opening in the pericardium by incision is preferable to aspiration, in consequence of the danger of wounding the heart when the latter method is employed. If the patient sur-

vive for some days, and suppurative pericarditis supervenes, similar procedures are indicated.

The best that can be said of wounds of the heart, is that the opinion formerly held regarding the instantaneously fatal result of these injuries is not correct. There are many trustworthy records of even severe wounds of the heart in which death was not immediate, though the immense majority eventually proved fatal. Otis details four such cases in his report, where the patients lived from an hour to two and a half years after perforation of one or more cavities of the heart by bullets; but he points out that the diagnosis in the latter cases may have been made on insufficient grounds.

CHAPTER XI

WOUNDS AND INJURIES OF THE ABDOMEN

WOUNDS of the abdomen are probably the most fatal class of injuries met with in war hospitals. The contents of the abdominal cavity are so readily lacerated, and the consequences of this accident are so extremely grave, that hitherto the mortality in these cases has been such as to render the prognosis almost hopeless. Until comparatively recent years penetrating wounds of the abdomen were treated on the "expectant" plan: nothing was done by the surgeon, except the administration of opium, and nature was "expected" to work a cure. The phrase "expectant treatment" has a particularly sinister application in this connection: nothing, properly speaking, was to be expected but the patient's early death under this method, and those who practised it seldom failed to see their expectations realised. More modern methods of treatment, though difficult of execution, afford a more hopeful outlook.

We know the results which are almost certain to be produced when a weapon or a projectile traverses the abdominal cavity—extravasation of the intestinal contents, or hæmorrhage which will not cease until mechanical means are employed to control it. We know that death may be looked for at an early period in the latter case, and at one but slightly more remote in the former; and we know that nothing but direct intervention can remedy these evils. If this be the correct way of considering these cases—and few surgeons will, in these days, take exception to this view—the indications for treatment are quite distinct. The abdomen must be opened, the hæmorrhage treated by the usual means, the apertures in the wounded intestines closed by suture, and the peritoneum

cleansed. No doubt, many cases so treated will die; but they will die in spite of sound scientific surgery, which, at all events, gave them their only chance of life, and they will not have been permitted to drift towards an almost certain death by being abandoned to the expectation that nature, unassisted, would effect what would be little short of a miracle.

Some few cases of gunshot of the abdomen had been treated by operation in different countries previous to 1885; but it has only been since that time that this important subject has been seriously taken up, and to American surgeons is the credit due for first bringing it forward.

Until that great epoch in surgery when the results of antiseptic methods of wound treatment had made it evident that a wound of the peritoneum was not an almost necessarily certain cause of death, all wounds of the abdomen were treated by rest and opium, the "expectant method," and nearly all proved fatal. When a happier issue occurred, it proved almost, but not quite, to a certainty that the intestines had not been wounded, nor any large vessel lacerated. I say not quite to a certainty, because undoubtedly true records of gunshot wounds of the intestines are available where recovery took place without operation; but they are so few, compared with the others, that they may be put down as the exceptions which go to prove the rule that operation is the proper course to pursue. When surgeons found that, under Listerism, the abdomen could be opened, and the peritoneum handled, cut, and sewn, without death resulting; and, even more, that opening the abdomen was not of itself a serious operation, but one the death-rate of which should be measured in small fractions per cent., they began to turn their attention towards the consideration of the possibility of operating in cases of gunshot wounds of the intestine. In 1881 Marion Sims read a very notable paper before the New York Academy of Medicine on this subject.[1] Parkes, of Chicago, calls it an appeal for operative interference in cases of penetrating wounds of the abdo-

[1] See *British Medical Journal*, 1881–82.

men, in place of the expectant treatment hitherto so universally adopted, and which had been followed by so large a mortality.

Marion Sims argued that, as ovariotomies and other extensive operations involving the peritoneum could, under Listerism, be recovered from, it was probable that gunshot wounds of the intestines and of the solid abdominal viscera might also be amenable to operative treatment. With a view, therefore, of discovering from experimental research what procedures to carry out, and how best to perform them, Dr. Charles T. Parkes, of Rush Medical College, Chicago,[1] undertook a series of experiments for the purpose of ascertaining the results to be obtained from immediate operation in the treatment of these injuries. He did not take up the general subject of wounds of the abdomen, but only that of wounds of the intestines from gunshot, and he confined his attention to an inquiry into the best methods of operation in these cases. His experiments consisted in firing revolver and rifle bullets of small calibre through the abdominal cavities of etherised dogs, thirty-seven animals being used, and immediately operating on the lesions found by abdominal section. At first no attempt was made to give any definite direction to the course of the bullet; but it was soon found to be necessary to do so, as otherwise the dogs died so rapidly from hæmorrhage that they afforded no opportunity for treatment. For this reason he was obliged to so direct the bullet as to prevent its wounding the large vessels, and, to a certain extent, the solid viscera, and so as to cause it to produce, as far as possible, only such injuries as usually come under the treatment of the surgeon, viz., those confined to perforations and contusions of the intestinal tube, with occasional injury to the large special viscera.

Even at this time, no doubt whatever existed as to the feasibility of the successful performance of operations on the contents of the abdominal cavity when undertaken in a civil hospital, with its complete equipment of materials

[1] "Gunshot Wounds of the Small Intestine," by C. T. Parkes, M.D., Chicago, 1884.

and appliances. But the circumstances are very different when these operations are done for gunshot wounds, with the peritoneum fouled by fæcal matter, and in a field hospital, with its crowd of wounded men urgently requiring assistance, the majority of whom might possibly derive more certain benefit from such assistance than the cases under consideration. The majority of men wounded in the abdomen on the field of battle are never brought to hospital at all, because they die where they fall from shock or hæmorrhage. This result necessarily happens when the larger arterial or venous trunks are lacerated. But hæmorrhage into the peritoneal cavity is curiously lasting and profuse when none but very small blood-vessels are severed. This may depend on the looseness of the tissues within the abdominal cavity preventing the setting up of tension on the cut ends of the vessel by the effused blood, together, no doubt, with the absence of the peculiar effect of air on the tendency of blood to form clots. When the abdomen is opened after a bullet wound, a large quantity of extravasated blood is usually found, and, even when only small vessels are implicated, the bleeding is found to be still going on: there seems to be little or no tendency to the formation of clots in the cut ends of arteries in the abdomen. Immediately an opening is made, the hæmorrhage tends to cease, but safety can only be assured by the application of ligatures. The deduction to be made from these facts is important, and goes to show that operative interference is the only means of cure in these cases. Persistent hæmorrhage is a sure and rapid cause of death, and bleeding has no tendency to cease spontaneously when occurring within the abdomen. When, therefore, we have evidence of its presence in this situation, we may know that nothing short of abdominal section will give any hope of saving life.

The other common cause of death following wounds of the abdomen is peritonitis from extravasation of fæcal matter. With a penetrating wound of the abdomen it is futile to *expect immunity* of the viscera from injury, and when the intestinal tube is opened, extravasation of its

contents and peritonitis are practically certain to occur. Here also, as in the case of hæmorrhage, no other means of effective treatment is available except abdominal section. In no other way can the escape of the bowel contents be checked, or the peritoneum be freed of the matter with which it is already contaminated, and which we know by experience is productive of one of the most fatal inflammatory processes met with in surgical practice.

Referring in general terms to the statistics of the comparatively recent wars, it may be stated that about 15 per cent. of the killed and wounded in battle are found to have received injuries in the abdomen; while about 11 per cent. of those found dead upon the field, and 4 per cent. of those admitted to the hospitals, have been wounded in the same region.

In discussing the subject of abdominal wounds and injuries, it will be convenient to divide them into—

A. Contusions of the abdominal walls, unaccompanied by wounds of the soft parts;
B. Non-penetrating wounds of the soft parts; and
C. Penetrating wounds of the abdominal parietes.

In the Crimea, amongst the British troops 19.1 per cent. of the cases of non-penetrating wounds and contusions of the abdominal walls died, and amongst the French 16.4 per cent. In the American War the death-rate was 7.9 per cent. in similar cases; while of *all* shot wounds 48.2 per cent., and of penetrating wounds 90 per cent., proved fatal.

Contusions of the abdominal walls may be simple injuries in which the damage is confined to these parts, or they may be complicated by rupture or laceration of any of the solid or hollow viscera or blood-vessels within the abdominal cavity. They are usually produced by large projectiles or their fragments when travelling at low velocities or striking tangentially, by kicks from horses, or other localised applications of violence to the abdominal parietes. No well-grounded reliance that these cases are uncomplicated by grave internal injuries can be placed on

the apparently trivial nature of the contusion, judging from the external signs, nor indeed upon the failure of severe constitutional and local symptoms to quickly appear in them.

The prominent symptom in these cases, even where no internal injury has been caused, is constitutional shock, sometimes amounting to collapse; but the degree in which shock is present is not always a criterion of the violence of the blow or of the real damage done. Many cases in which shock is at first very profound rapidly recover, and are quite convalescent in a few hours or in the course of a day or two; on the other hand, cases in which this symptom is slight may have sustained rupture of one of the viscera. Contusions over the region of the solar plexus are especially liable to be followed by severe signs of shock, but the significance of this condition always depends rather on its duration than on the degree in which it is present. When unaccompanied by any visceral lesion, no matter how severe it may be soon after the receipt of the injury, the shock usually passes off in a few hours; whereas with internal lesion it may, at first, be either severe or slight, but in either case its duration will certainly be more prolonged. When shock lasts for many hours, and does not lessen in severity, it is suggestive that this is due to extravasation of the bowel contents or to grave injury of one of the solid organs, and not to the effects of mere concussion of important nerve structures. Pain of a severe, but usually of an intermitting type, is almost always one of the results of abdominal contusion. Nausea or vomiting is a very common symptom, and the temperature may be above or below the normal; more often it is the latter.

Contusions with Rupture of viscera are accompanied by the symptoms just mentioned, and in quite as variable degrees of severity, together with some others which have special reference to injuries of particular organs. The differential diagnosis between simple contusion of the abdomen and contusion accompanied by internal rupture, is extremely difficult during the early periods of the case; but if the patient survive long enough, symptoms point-

ing to lesions of the intestine or of special organs, as the case may be, will develop, and leave but little doubt in the surgeon's mind as to what portions of the abdominal contents are implicated. These symptoms of later occurrence will be dependent on the escape of fæcal matter and gas from the intestines into the general cavity of the peritoneum; on extravasation of blood from lacerations of blood-vessels or of solid organs, and on interference with the functions of certain organs, such as the liver and kidneys. Any of the solid or hollow viscera within the abdominal cavity, or any of the blood-vessels, large or small, may be ruptured by a mere contusion, and sometimes by one apparently of no great violence. The order of frequency of these internal injuries of the several organs due to contusions is probably as follows—liver, spleen, kidneys, stomach, small intestine, large intestine. They are extremely grave cases; the large majority of those in which solid viscera are implicated dying immediately from shock, or rapidly from hæmorrhage, and when the stomach or intestines are ruptured, from shock, hæmorrhage, or peritonitis, within the first two or three days.

The Differential Diagnosis of simple contusion from contusion complicated by visceral lesion is not only of great importance to the patient, but a matter of great difficulty for the surgeon to arrive at during the first few hours of the case. Later, there will be no difficulty in distinguishing between the two classes of cases; but the occurrence of the later symptoms, which will render diagnosis easy, will be due to progressive hæmorrhage or peritonitis, conditions which, if waited for, will reduce the patient's chances of recovery to the last degree. Shock, pain, and nausea or vomiting are the early symptoms in both cases: but they may be well or ill marked in either case; no reliance can be placed on the degrees in which they are present to distinguish one from the other. Tympanites and abdominal distension are more common with intestinal lesion than with contusion, and they are of sufficiently early occurrence to be of use to assist the surgeon in forming his opinion of the probable nature of the injury.

The primary symptoms produced by simple contusion tend to steady diminution, while those of visceral lesion gradually increase in severity, and others are added to them. They may be as acute, or even more acute than when internal injury has occurred, but their duration is not so prolonged. It is impossible at first in these cases to form any certain diagnosis on this point; but when the surgeon, after some hours, observes that the signs of shock, the pain, and the vomiting do not lessen, but that, on the contrary, they become more marked, and that tympanites, abdominal distension, and dulness in the flanks also supervene, he should begin to suspect visceral lesion, and to consider the means of treatment he must adopt to relieve the patient of the almost certainly fatal condition which probably exists—hæmorrhage from a solid viscus or a lacerated vessel, or extravasation of fæces from a ruptured intestine, or, more probable still, a combination of these complications.

Once the suspicion of internal injury becomes strong and well founded, there is no time to be lost. Hæmorrhage within the abdomen, of sufficient importance to produce symptoms, will not cease spontaneously, and extravasation of fæces once begun sets on foot a peritonitis which nothing but laparotomy can be expected to cure, and every half-hour's delay lessens the probability of the operation producing the desired effect. That cases of this kind *have* recovered without laparotomy, is, no doubt, true; but this does not diminish by a grain's weight the force and propriety of this line of reasoning. If, from one reason or another, these operations cannot be undertaken in warfare —if the field hospitals be so crowded that the requisite time cannot be devoted to them; if the necessary antiseptic materials be not available; if the surgeon cannot rely upon his skill to make a water-tight seam in a ruptured gut—then by all means let expectant treatment be pursued: "keep the patient at rest, with his shoulders raised and his legs flexed, and give him opium;" let Nature have her chance of working the impossible! But Nature, aided by ligature of severed vessels, suture of ruptured intestines,

and cleansing of the peritoneum, is more likely to act effectively than when left to her own resources.

The Symptoms of visceral lesion from contusion of the abdominal walls which are common to all cases, are, as already stated, shock, pain, and vomiting; these are rapid in their onset, but extremely variable in degree. Shock may be severe or slight, and, in exceptional cases, there may be none; the surface is blanched, cold, and perspiring; the pulse fluttering and almost imperceptible, and the respirations sighing. The pain is usually, but not always, of extreme intensity. Vomiting is a constant sign.

When hæmorrhage occurs, and is not of such severity as to produce death almost immediately, the symptoms resulting from it soon make their appearance: the patient becomes pulseless or nearly so; he is extremely restless, incessantly moving from one side to the other in bed; he gasps for air, apparently from a sense of want of oxygen, though his respiration is unimpeded and the face is pallid. The dependent portions of the abdominal cavity become filled with blood, and dulness on percussion becomes perceptible in the flanks. This dulness varies in position as the patient is turned to one side or the other. Retention of urine is present in about 50 per cent. of the cases, though not necessarily indicating damage to any portion of the urinary tract. Hæmorrhage is usually the result of rupture of the liver or spleen, sometimes of laceration of a vessel in the mesentery or of one of the large abdominal arteries or veins; but it seldom occurs to any great extent from intestinal rupture.

When the internal lesion is in a hollow viscus, the primary symptoms continue or become more marked, and gradually have included with them those of peritonitis. The pain becomes more general, the vomiting increases, and tympanites, tenderness, and distension with rigidity of the muscles of the abdominal walls make their appearance. Jobert has drawn attention to the importance of the occurrence of sudden tympanites, produced by the escape of the intestinal gases into the general cavity of the

peritoneum, as an early sign of rupture of any portion of the intestinal tract; but tympanites may result from paralysis of the gut due to the blow on the abdominal walls, and it is likely to be general if this condition occurs low down. It has also been pointed out—I believe, by Flint, an American surgeon, but I am unable to give the reference—that a slight escape of flatus from a ruptured intestine may cause the liver dulness to disappear by insinuating itself between the upper surface of the liver and the abdominal walls.

Upon these symptoms, or upon varying combinations of them, the surgeon must rely for data on which to found his diagnosis of visceral lesion in cases of abdominal contusion unaccompanied by wound of the parietes; and it is incumbent on him to be acutely watchful for their appearance, for upon the promptness with which he recognises them, and acts on the indications supplied by them, will the lives of patients injured in this manner hang.

The Treatment of a case of contusion of the abdomen should be carried out at first by the use of the usual means directed towards recovering the patient from the condition of shock and collapse which so frequently accompanies this injury. The position in bed should be with the shoulders raised and with pillows under the knees so as to flex the hips and relax the abdominal muscles, while his surroundings should be as quiet and restful as can be obtained under the circumstances. Gentle compression of the abdomen by means of a wide roller bandage over a thick layer of elastic cotton-wool sometimes tends to relieve pain; hot fomentations have a similar effect, and may be used if there are no signs of internal hæmorrhage. When pain is intense, the indication for the use of morphine subcutaneously might appear to be quite clear. But it must never be forgotten that the first twenty-four hours of the treatment of these cases is a period of watchfulness for the development of the graver symptoms pointing to visceral lesion, and that morphine, while it has no effect in obviating the results of rupture of the intestine, masks the signs on which the surgeon depends for its early recognition and

which warrant him in the performance of a laparotomy as the only method of treatment holding out an expectation of recovery. Opium and its derivatives should therefore be withheld if possible until all suspicion of internal lesion has been removed by lapse of time; but if the pain, as is sometimes the case, be so extreme as to necessitate their use, a subcutaneous injection of one-quarter grain of morphine is less objectionable than the repeated administration of opium by the mouth, as was formerly the practice under the circumstances indicated.

If the primary symptoms of the case diminish, and if no signs of hæmorrhage or of fæcal extravasation present themselves during the first twenty-four hours, hope may be entertained that no grave internal injury has occurred, and the expectant treatment may be continued. But if, on the contrary, the symptoms of shock deepen, and those of extravasation of blood or of fæces into the peritoneal cavity present themselves, the surgeon must consider the evidence pointing towards the advisability of abdominal section for the repair of the internal lesions, and, if he decides in its favour, the sooner it is performed the better. (In order to avoid repetition, the discussion of this subject may be postponed to a subsequent page, where it may be more appropriately dealt with under the heading "Treatment of Penetrating Wounds of the Abdomen.")

The prognosis in cases of abdominal contusion should always be a guarded one, in consequence of the impossibility of determining the absence of internal injury, if we judge only from the visible signs of external injury, and the degree of force to which the abdominal walls have been subjected, apparently slight blows sometimes producing rupture, and severe ones occasionally not doing so. Doubt must always exist as to the nature of the case, and time alone can remove it. When visceral lesions are present, they are extremely fatal: 30 out of 52 cases reported during the American War died. The causes of death are shock, hæmorrhage, and peritonitis.

Non-Penetrating Wounds of the abdomen should be treated according to the general principles applicable to

wounds of the soft parts elsewhere. Clean, incised wounds by swords should, after thorough disinfection, be accurately closed, the muscles by buried silk or catgut sutures, and the skin by horse-hair or silk-worm gut, dry gauze and wool dressings being applied.

Lacerated wounds produced by shell fragments should have all dirt and other foreign matter carefully removed by washing with an antiseptic solution. They may either be left open or be partly brought together by sutures; in the latter case all shreds of contused tissue should be removed by the scissors, and a drainage tube put in, and in both cases they should be thickly dusted with iodoform, and covered with gauze wrung out of sublimate lotion, and alembroth wool. If suppuration should occur, any adhesions which may have formed should be slightly broken down to give exit to discharge, and prevent the burrowing of pus between the muscles.

Non-penetrating punctured wounds, due to thrusts by side-arms, are particularly liable to contamination, and should have the skin openings slightly enlarged to ensure complete disinfection, and be well washed with one of the weaker solutions; the dressing should be iodoform gauze wrung out of sublimate lotion, and a pad of wool.

Penetrating Wounds of the Abdomen.

Penetrating wounds of the abdomen may be divided into (*a*) those unaccompanied by laceration of viscera, and (*b*) those in which injury of the abdominal contents is present. The former, as will appear later, are of extreme rarity.

Many works on military surgery divide these injuries, for the purpose of description, still further, into those in which protrusion of viscera occurs, and, again, according as to whether the protruded viscera are injured or uninjured. But this minute subdivision is quite unnecessary, in the first place, because protrusion of viscera hardly ever occurs in wounds produced by small-arm projectiles, and not frequently in wounds resulting from sword-cuts or fragments of shell; and, in the second, because this com-

plication in no way changes the principles of surgical treatment required for their cure.

The mortality which has hitherto followed penetrating wounds of the abdomen, as seen and treated in war hospitals, has been extremely high. The French lost 91.7 per cent. of their cases in the Crimea,[1] and the English 92.5 per cent.[2] In the American War the death-rate was 90 per cent.

In all cases of wounds of the abdominal parietes, whether produced by side-arms or by projectiles, the first point to be determined is the existence or otherwise of penetration of the abdominal cavity. This should be clearly ascertained, and at the earliest possible moment, by exploration with the finger, and if the skin wound be not large enough, it should be extended for this purpose. Exploration and probing in these cases were quite forbidden by the surgeons of earlier days; this naturally followed from the fact that in former times a certainty of penetration did not affect the treatment to be pursued. But now so much of the treatment depends on the fact of penetration or otherwise, and on an accurate knowledge of this one point, that all doubt regarding it must be cleared away, though the necessary precautions must be taken against contamination of the wound. As MacCormac rightly says:[3] "If penetration exists and remains unrecognised, and nothing is done, after a short interval the occurrence of peritonitis will determine the diagnosis: tympanitic distension of the abdomen, agonising pain, ceaseless vomiting, tendency to collapse, thready pulse, and clammy surface make their appearance, and a fatal issue soon follows. When the diagnosis is established in this way the services of the surgeon are then no longer called for."

The importance of ascertaining whether the abdominal cavity has been opened or not, depends on the extremely high probability, especially in gunshots, which exists of injury to the abdominal contents when penetration has occurred.

[1] Chenu. [2] Matthew.

[3] "Abdominal Section for the Treatment of Intraperitoneal Injury," Sir William MacCormac, 1887.

Parkes's experiments on dogs, already alluded to, prove that no expectation can be entertained, and no reliance can be placed, on the safety of the intestines and solid organs within the abdomen once the cavity has been traversed by a bullet; and further, that if the intestines are opened in the very smallest extent, extravasation of their contents will necessarily take place. Not one single exception to this statement was noted by him in his experiments, where several hundred wounds of the various hollow viscera were under observation. The experience of the American War is to the effect that minute punctures are not always accompanied by extravasation, but that wounds exceeding four lines in length were generally fatal unless art came to the relief of nature. It has been suggested that the hernia of the mucous coat, which always takes place when the intestine is wounded, is sufficient to prevent extravasation in man, as some experiments have shown it to be in cats and dogs, although in none of Parkes's cases was it effective for this purpose. But hernia of the mucous coat means a protrusion of a moist and septic surface against a serous membrane which is peculiarly prone to inflammation, although it is, at the same time, powerful in combating and controlling the results of this process. No doubt a peritonitis produced in this way, when the escape of fæcal matter is small in amount, is more likely to be a localised one, resulting, by the aid of rapidly formed adhesions, in a circumscribed abscess not very dangerous to life. But experience has taught that cases of this hopeful character are very exceptional. A bullet traversing the intestinal tube produces an actual loss of substance in the gut at least equal to the area of its cross-section; and even when striking it tangentially, makes openings of a size quite unlikely to become plugged by mucous membrane, or to offer any resistance to the extravasation of the contents of the gut.

Then again, it is almost impossible to imagine the passage of a bullet through the abdominal cavity without injury to the intestines or special organs: the rate per cent. of this occurrence must be represented by a very small

fraction. It is less unlikely to happen in cases of penetrating wounds by side-arms; and nine cases of this kind due to bayonet thrusts are recorded by Otis—seven of these suffered from peritonitis, but six recovered without having shown signs of intestinal lesion. Malgaine disbelieved in bullet wounds of this region unattended by internal injury; Larrey, with all his large experience, states that he only saw one such case; and many of those recorded as instances of the kind are of doubtful value, in consequence of the possible inaccuracy of diagnosis. When, therefore, the diagnosis of penetration of the abdomen by gunshot is distinctly ascertained, we may assume the certain presence of wound of the abdominal viscera; and when the intestinal tube is opened, even in the smallest degree, we may assume the extravasation of its contents. Sir William MacCormac speaks with full experience and in no uncertain voice regarding this point:[1] "The bowel is nearly always perforated, fæces are extravasated, and very frequently there is some other serious complication as well."

My object in insisting on the extremely high probability of injury to the abdominal viscera in cases of penetrating wounds, and on the certainty of fæcal extravasation if the intestines are opened, is to be enabled to direct the reader's attention to the necessity of performing laparatomy in these cases.

Fæcal extravasation is the immediate cause of what is probably the most fatal inflammatory process known to surgeons. The cases in which it does not occur on account of the minuteness of the wound in the gut are quite exceptional: MacCormac, Trelat, and others declare that 99 per cent. of injuries to the intestine will be followed by the escape of fæces, and by no other means than abdominal section can it be made to cease. When a bullet enters the abdominal cavity, we may disregard the absence of proof of internal injury, and assume it as certain. Reclus, Beck, Tilleaux, and other surgeons recommend waiting for the appearance of signs of hæmorrhage or of peritonitis as the necessary indications before operating; while Nussbaum,

[1] *Op. cit.*, p. 22.

Trelat, Greig Smith, Lucas, MacCormac, and a host of others advise immediate operation when penetration has been diagnosed, because they consider that peritonitis is certain to occur.

Peritonitis from extravasation is the more common cause of death following penetrating wounds of the abdomen; hæmorrhage is the other complication which so often proves fatal in these cases; but amongst those who live to reach the field hospitals, peritonitis is the more often fatal of the two. The same line of argument applies for the necessity of the treatment of hæmorrhage by laparotomy as in the former case. The tendency of bleeding from lacerated vessels within the abdominal cavity, even when these are small, to persist until treated by ligature, has been already allluded to. No dependence can be placed on other methods, such as the application of cold or the use of drugs; through an *abdominal section only* can the necessary procedures be carried out.

The two great causes of death are, then, only amenable to effective treatment by operation. The conditions of the internal organs are only to be ascertained when the abdomen has been laid open by this means. Suture of the apertures in the intestine, or resections of portions of the tube, can be performed; ligatures can be applied to bleeding vessels; and the peritoneum can be irrigated, and cleansed of septic matter and blood. In the absence of these measures, death is almost certain from general peritonitis or internal hæmorrhage. Even if a case so treated prove, on operation, to be one of those very exceptional ones of penetration without visceral lesion, no harm is done, for the death-rate of exploratory operations on the abdomen is small. But if some danger be incurred, we are still warranted, from the patient's as well as from the surgeon's point of view, in running the risk, taking into consideration the extremely fatal nature of these injuries when left to the unaided resources of nature. The treatment, therefore, must be by laparotomy, because the alternative means abandoning the patient to almost certain death. There is no "happy mean" which one can console oneself by adopt-

ing: it is laparotomy or nothing, therefore it must be laparotomy.

Once penetration is ascertained, the sooner the operation is performed the better. In this connection, Coley's statistics show that 46.1 per cent. of those cases in which laparotomy was performed in the first twelve hours, recovered; while of those operated on later, only 22.7 per cent. recovered.[1] Lühe's statistics are still more in favour of operating the first twelve hours after the receipt of the injury; indeed, the more experience we gain of this matter the stronger is the evidence in favour of early interference.

Marion Sims, in the paper already referred to at the beginning of this chapter, states his opinion that the fatal cases of gunshot wounds of the abdomen — setting aside those who die of hæmorrhage—die of septicæmia, produced by the absorption of septic matters from the collections of bloody serum which, as is proved by post-mortem examination, always form in these cases, and not from peritonitis, properly so-called. He points out that most of them die during the first forty-eight hours, and that this is too short an interval for death to be the result of the latter cause. But this would not influence in the smallest degree the line of treatment to be adopted; for the septic fluids to which, according to him, the fatal result is due, cannot be removed, and the peritoneum purified, otherwise than by abdominal section.

The German Report supplies some statistics regarding the gunshot wounds of the abdomen treated during the war of 1870–71, but we are not informed whether they refer to the German army only or to the armies on both sides. There were, the Report states, 5743 cases of this class; 72 per cent. of them were non-penetrating wounds, and in 28 per cent. the abdominal cavity was opened: 25.7 per cent. of all the cases died, while 76 per cent. of the cases of penetrating wounds proved fatal. The proportion of penetrating to non-penetrating wounds was, according to this, extremely small, viz., 28 to 72 per cent. In

[1] German Report, by Von Coler.

future wars this ratio is not at all likely to be maintained; it will, more probably, be reversed, for the abdominal walls offer, practically, no resistance to the entry of the modern small-arm projectile even at the longest ranges.

The ileum is the portion of the intestine most frequently injured by gunshots, and wounds of it are the most fatal. Otis states that he is unable to refer to a single case of recovery from undoubted gunshot of the small intestine during the American War, whereas there were at least 59 recoveries from wounds of the large intestine. Injuries to the bowel above the brim of the true pelvis are far more fatal than those below that line, although the rectum or bladder, or both, may be implicated. MacCormac reports three recoveries in cases of the latter kind, and there are many others on record.

The logical outcome of what has been stated above—viz., that all penetrating gunshots of the abdomen require the operation of laparotomy for their cure, because in these cases internal lesions which cannot otherwise be repaired are certain to have occurred—would be that the symptoms and diagnosis of visceral injury need no further discussion. The symptoms of visceral lesion almost all present themselves at a time subsequent to that at which operative interference can be made with greatest advantage to the patient, and the operation should prevent their appearing at all; why, then, discuss the later symptoms, which can only occur if the proper treatment has not been adopted? It is because many surgeons may not be willing to perform laparatomy while there is still no clear evidence of its necessity, but may desire to await the onset of signs pointing to operation as the only means of treatment and as a last resource; and also because all cases do not come under the surgeon's observation at an early period, but only after such delay as may have given time for symptoms to arise. For these reasons it may be well to indicate the signs which point to perforation of the intestines, and to supply the data on which a diagnosis may be founded. But it must always be remembered that the case in which symptoms have been awaited, or in which such delay has neces-

sarily occurred before they come under treatment that symptoms are already apparent, have had their chances of recovery very much reduced.

The Symptoms of Wound of the Intestine are fairly certain in the indications they afford, but they are late in making their appearance. There are no signs likely to be observed by the surgeon which point distinctly to this complication during the first six or eight hours after the receipt of the injury. The earliest symptom which should lead to suspicion of wound of the intestine is the persistence or the increase of the signs of constitutional shock. Yet not in all cases of abdominal wound, even when the viscera are implicated, is shock well marked. It is so usually, but its absence cannot be relied on as evidence of the escape of the bowel from injury. Parkes, speaking of shock, states that there is no peculiarity in this matter in wounds of the abdomen, and that when this symptom became well marked it was always due to excessive internal hæmorrhage. In making this statement he was, no doubt, referring to his experiments on dogs, and probably was correct so far; but it certainly does not apply to men, in whom abdominal wounds, and especially penetrating wounds, are usually accompanied by symptoms of severe shock. But the importance of this symptom depends on its duration. If it continue, and especially if it become more profound, the probabilities are that there exists serious damage to the contents of the abdominal cavity to account for it. Pain and vomiting are also symptoms, the persistence or increase of which are indicative of wounds of the intestine. At first the pain is localised, and "sharp" or "burning" in character; later it radiates all over the abdomen, and it may extend over the chest and groins. These are all symptoms which may be dependent on the general injury of the abdomen, irrespective of internal lesion: other signs there are which are due to the mechanical effects of a perforation in the intestinal tube.

Tympanites from the escape of the intestinal gases into the general cavity of the peritoneum is a sign on the value of which some authors have laid great stress. Otis refers

to "sudden meteorism" from this cause as an "important sign of wound of the bowels." Mr. F. Treves,[1] on the other hand, considers it a sign of no diagnostic value. It is of rare occurrence; and tympanites due to paralysis of the intestine from injuries other than perforations may be mistaken for it. The disappearance of the normal liver dulness brought about by gas free in the peritoneal cavity has already been alluded to.

Emphysema of the abdominal walls spreading from the wound in the parietes sometimes occurs; but both tympanites and emphysema are rare symptoms, and not certain indications when present.

There are some few signs which are certain evidence of intestinal lesion—escape of intestinal gas by the wound, protrusion of wounded bowel, the appearance of fæces or of intestinal worms at the external wound, and the passage of blood or of the bullet itself by the anus; but, with the exception of the first two, they occur so late as to be of no practical value with regard to the treatment of the case.

The escape of intestinal gas by the wound is a symptom rarely observed by the surgeon, either because it escaped at the moment of the receipt of the wound, or because the aperture becomes closed by an uninjured coil of intestine. It is, therefore, not a sign of much practical utility in diagnosis.

Protrusion of intestine, wounded or unwounded, also seldom happens, except in cases of long incised wounds produced by sword-cuts, or in those extensive lacerations resulting from large projectiles or fragments of shell; it is hardly ever seen in cases of wounds by the smaller kinds of missile.

The appearance of fæcal matter in the external wound is, of course, proof of intestinal lesion, but it is of exceptional occurrence, and late in appearing. Out of 48 cases MacCormac only saw it in 1; Bernard saw it only in 3 cases out of 36; Otis, on the other hand, considers it a common occurrence; and the German surgeons report it in 21 cases

[1] "A System of Surgery," vol. ii., 1896.

out of 59 in the war of 1870–71, of which 14 were wounds of the small intestines.[1] Most authorities agree with MacCormac, Bernard, and Delorme, that the appearance of fæces in the wound is only exceptional, rather than with Otis and the German surgeons. The much greater facility which exists for the escape of fæces into the cavity of the abdomen than for its passage externally by the wound, and the improbability of the apertures in the intestines remaining for any time in apposition with that in the parietes, is sufficient explanation of the rarity of this certain sign. Moreover, it is a symptom which is seldom seen before the lapse of from twenty-four to forty-eight hours, and therefore the more frequently these injuries are treated by early laparatomy the less often will it be observed. In fact, that fæces should be allowed to appear at the external wound is, in the majority of cases where it is seen, evidence of bad surgery, inasmuch as it shows that the only effective treatment which could prevent its occurrence has not been adopted sufficiently early.

The appearance of intestinal worms at the external wound has been noted[2] sufficiently often to make a reference to this symptom necessary; but its occurrence is, of course, very exceptional.

A similar statement may be made regarding the passage of the bullet by the anus. Otis reports some eight or nine such cases as having been observed during the American War. The bullet in these cases may either have become arrested within the lumen of the bowel, and so be passed directly with a motion, or it may have lodged in the immediate neighbourhood of a coil of intestine—usually the colon or rectum—and produced an abscess, ulcerating its way into the bowel, and being expelled some days or weeks after the receipt of the wound.

The escape of blood by the anus is also a rare sign; in any case, it is one which is late in making its appearance, and therefore of no value as an indication for treatment. When the wound is in the small intestine, the blood is of

[1] Delorme, *op. cit.*, vol. ii.
[2] Otis, Baudens, Guthrie, Salzmann, Poland, &c.

a dark colour; and when the colon or rectum is implicated, it appears in a form more nearly approaching pure red blood.

The Diagnosis of Visceral Lesion in cases of penetrating wounds of the abdomen is difficult, if not impossible, during the first few hours after the receipt of the injury. The probability of its presence may be inferred from observation of the position of the wound and the general condition of the patient; but once penetration of the abdominal cavity has been ascertained, no waiting for the occurrence of the certain signs above referred to is permissible if treatment by operation is to be undertaken.

Parkes,[1] speaking with reference particularly to the abdominal cavity, states that nothing can be more uncertain and erratic than the course of a bullet through the body: observation of the wounds of entrance and exit, he says, gives one no idea of the true line of the bullet track; contact with almost any tissue in the body, muscular fibre in a condition of contraction, an edge of fascia, the skin, or even a distended knuckle of intestine, is sufficient, he considers, to turn the projectile from its direct line of flight. The explanation of this curious statement must be that the wounds observed by him in his experiments were produced by bullets travelling at a low rate of velocity, and even then his experience was exceptional. The exact contrary is true of a small-bore bullet at any rate of velocity. Possible at extremely long ranges the iliac or spinal bones might deflect even a modern bullet; but under other circumstances the direction of the bullet track and the positions of the entrance and exit apertures will, in case of wounds of the abdomen especially, afford almost infallible indications of what structures have been traversed by it. Indeed, attention to these points are the only means which are at first available. Later, if an operation is not performed, the other signs will present themselves, signs depending almost exclusively on hæmorrhage and fæcal extravasation.

Senn, of Milwaukee,[2] has recommended and practised

[1] *Op. cit.*, p. 12.

[2] "Intestinal Surgery," by N. Senn, M.D., Chicago, 1889.

the inflation of the intestinal tube with hydrogen gas as a means of diagnosis of perforation of the bowel in cases of abdominal injury from any cause. He found experimentally that it is possible to inflate the whole intestinal tract with air or gas injected into the rectum, and he selected hydrogen for this purpose, because it is sterile, unirritating, and capable of rapid absorption. Dr. Senn made experiments both on animals and men which proved that the intestines could be distended from end to end by hydrogen gas under a pressure of less than one pound, and that this amount of force produced no lesion of the intestinal walls if the injection were carried out slowly. When this method is employed for the diagnosis of perforation of the bowel in penetrating wounds of the abdomen, the gas will escape from the intestine at the perforation, if one has occurred, and appear at the external wound, where it may be lighted. This would, of course, be positive proof of intestinal lesion. But the failure of the gas to escape is not an equally reliable evidence of the integrity of the gut; a perforation may exist and yet the gas may not appear at the wound in the parietes. Senn practised this operation in three cases of gunshot of the abdomen—one in which the stomach was wounded, and two in which the intestines were perforated. One of the latter was especially instructive, as showing a particular use of the method. Laparotomy had been performed, and eleven perforations had been closed by suture, when injection of hydrogen disclosed another perforation in the anterior wall of the rectum which had been overlooked; this also was sutured, and the man recovered. Some other American surgeons besides Senn have used this method with satisfactory results, but I am not aware that it has been practised in this country or on the Continent.

Inflation of the intestine would, no doubt, afford direct evidence of perforation in the large majority of cases where this had occurred, but it requires considerable time for its performance. It must be done under an anæsthetic; it adds to the condition of shock and collapse already, perhaps, only too well marked; it may fail to indicate an ex-

istent perforation; and when we remember the extreme improbability of a projectile traversing the abdominal cavity without producing visceral lesion, we may rightly hesitate to subject a case of gunshot injury to this means of diagnosis. On the other hand, in cases of penetrating wounds of the abdomen by side-arms, where the probability of immunity of the intestines from injury is much greater, and consequently the necessity for the early performance of laparotomy much less apparent, than in gunshot cases, the method may prove to be justifiable, especially when the state of the patient is favourable as regards his general constitutional condition. Further, it should be of use, as in Senn's case above referred to, for the purpose of showing, during a laparotomy, that all the apertures in the bowel have been successfully sutured and none overlooked.

The diagnosis of intestinal lesion in general is difficult; the differential diagnosis of wound of the small intestine from that of the large intestine is still more so. Here we must depend principally on the position of the wound. A wound in the central area of the abdomen, in the region of the umbilicus, will probably be complicated by lesion of the small intestine, while wounds situated in the flanks are more likely to implicate the ascending or descending colons, and those below the costal margin the transverse colon and stomach. If fæcal matter should escape by the external wound, its condition as regards fluidity or hardness may afford evidence as to whether the lesion is in the small or large intestine. Dark-coloured blood in the stools, localised tympanites, and the early onset of peritonitis are indicative of injury to the small intestine; while the passage of red blood at stool points to wound of the large intestine. But these extreme niceties of diagnostic procedure are hardly required in these cases, because great accuracy in this matter, if achieved, makes no difference in the treatment required for their cure. Penetration or otherwise is the all-important question, and the only one on which the treatment should be made to depend. This being settled in the affirmative, operative interference

should be undertaken without delay, or with only such delay as may permit the patient to recover sufficiently from the shock and collapse consequent on his injury to enable him to bear the necessary manipulations.

The Prognosis and Mortality of Wounds of the Abdomen.—The prognosis in these cases is extremely bad, penetrating wounds of the abdomen being probably the most fatal class of injury met with in surgical practice. Of all the cases seen in war hospitals, penetrating gunshot wounds of the abdomen are the most fatal. During the Crimean War of 120 cases amongst the English troops in which penetration *was believed* to have occurred, only nine recovered, and in many of these the accuracy of the diagnosis of penetration was doubtful;[1] this gives a death-rate of over 92 per cent. During the American War the mortality was 90 per cent.

Incised and punctured wounds from side-arms are not such grave injuries, the probability of visceral lesion being less in these than in gunshot cases. During the American War punctured and incised wounds of this region, taking those with and without *known injury* to the contained viscera together, gave a mortality of slightly over 51 per cent. Both these classes of wounds are somewhat less likely to be complicated by intestinal lesion than are gunshot cases, and when they occur in punctured wounds the apertures in the intestines are certain to be fewer in number, which will account for their lower death-rate.

Wounds of the large intestine are less fatal than those of other portions of the intestinal tract. Those of the transverse colon are, however, more dangerous to life than wounds of the cæcum, ascending or descending colons, sigmoid flexure, or rectum, the fatality of which probably follows in the order named. Several circumstances in connection with the large intestine help to explain this fact: in certain parts of its course a wound may be extraperitoneal; this portion of the gut is more fixed in position, and its contents are less fluid than those of the small intestine; and, finally, it is more closely applied to the abdominal

[1] Matthew.

walls. All these conditions tend to prevent general contamination of the peritoneum by extravasation of its contents. Otis recorded 59 cases of recovery from wound of the large intestine; whereas he states, as has been already mentioned, that he is unable to refer to any well-authenticated case of recovery from gunshot wound of the smaller bowel. Fæcal fistula is a common sequela of wound of the large intestine.

The prognosis and death-rates following on wounds of the solid abdominal viscera will be referred to subsequently, when the treatment of these complications is being discussed.

The Treatment of Penetrating Wounds of the abdomen complicated by known lesion of the contained viscera is thoroughly agreed upon by modern surgeons. Whether the internal injury be laceration of a blood-vessel, of a solid organ, or of a portion of the intestinal tube or of the bladder, surgeons now recognise that recovery is extremely improbable, if not actually impossible, unless an operation be performed for its repair. Hæmorrhage from even a small vessel within the abdomen may cause death if a ligature is not employed to control it; bleeding from one of the solid organs is not likely to cease unless some mechanical means are applied; and extravasation of the contents of the hollow viscera is practically certain to occur, and set up a peritonitis of an extremely fatal character, unless means are taken to cut it short. The treatment of such cases may therefore be summed up in a word—laparotomy, for the discovery and operative repair of the damage which the vessels and organs out of sight may have sustained.

But in cases of wound of the parietes evidently opening the abdominal cavity, yet unaccompanied by distinct signs of visceral lesion, some surgeons are content to await events, and to postpone operation until sufficient symptoms arise to justify the belief that internal injuries exist which call for surgical interference for their cure. This would, no doubt, be sound surgery if the cases of penetrating wounds of the abdomen in which visceral lesion occurs

were the exceptions to the rule. If visceral lesion occurred in only 2 or 3 per cent., no surgeon would think of operating before he had good evidence that his interference was imperative, not would he be justified in doing so. But in cases of penetrating gunshots of the abdomen the ratios just named are reversed; indeed, the probability is that to say that in 2 or 3 per cent. of these cases the internal organs will escape injury is to place the proportion too high. The true ratio cannot be accurately ascertained; but it is certain that it is so small that it may be disregarded, and that in penetrating wounds of the abdomen visceral lesion may be assumed, and the necessity of operation taken for granted when the situation of the wound or the line of the bullet track corresponds to the positions of the hollow or solid viscera.

Wounds of the solid organs will require laparotomy, for the purpose of stanching hæmorrhage, or, in some cases, for the removal of the organ implicated; and wounds of the hollow viscera necessitate similar treatment for the purpose of suturing the apertures found in them, and cleansing the peritoneum, which is certain to have been fouled by their extravasated contents. Unless these procedures are effectively carried out, death is practically certain, either from acute hæmorrhage or peritonitis. Even if no hollow viscus is found to have been perforated, and if the bleeding has ceased—which is unlikely—blood clots are certain to have accumulated in the dependent parts of the abdominal cavity, and will need removal; otherwise the effused blood will prove a fertile medium for the growth of micro-organisms, which the general traumatic condition will permit to escape from the intestines, or which the missile or particles of clothing may have carried in with them, and suppuration and peritonitis will supervene. Thus laparotomy in these cases will hardly ever be merely "exploratory," for by the "toilet of the peritoneum," even when no other measures are found necessary, one of the great dangers of a fatal issue in the less severe cases is removed.

The great danger in the treatment of this class of in-

jury is that the surgeon, from one cause or another, should allow himself to await the appearance of symptoms indicative of visceral lesion before proceeding to interfere by operation. If he has the necessary antiseptic materials at hand, nothing should be permitted to cause delay except the fact that the patient's general condition does not warrant interference. The symptoms, the appearance of which the surgeon will look for if he waits, are those of septic peritonitis, and when this condition is present it is already too late for operation to give any but the faintest hope of cure. The mortality of wounds of the abdomen believed to be cases of penetration has been about 90 per cent. when not treated by laparotomy; and in many of the 10 per cent. who recovered, penetration had probably not occurred at all. On the other hand, Morton, of Philadelphia,[1] has collected statistics of 234 cases operated on in Europe and America with 138 deaths, or a mortality of only 58.9 per cent.

The majority of surgeons admit the necessity of operation when penetration has been diagnosed, and the best authorities insist on its performance as early as possible, that is as soon as the patient has recovered from the immediate constitutional effects of his injury sufficiently to enable him to bear it. In this connection Sir William MacCormac writes:[2] "It will be more reasonable, then, to submit the patient to the less serious risk incurred by abdominal section, than to leave him in deadly peril from the consequences of a wounded intestine or a bleeding vessel;" and further: "If we await the outbreak of peritonitis, the patient's chances of recovery after operation will be greatly diminished; operation is practically useless after twenty-four hours have elapsed, or when general peritonitis has set in." Jacobson[3] says: "Death from septic peritonitis or hæmorrhage is so common as to justify our urging, in most cases, as early an operation as possible after the diagnosis of peritoneal perforation is made." Erichsen[4] con-

[1] "Abdominal Section for Traumatism," by Dr. T. S. K. Morton.
[2] "Abdominal Section," p. 22.
[3] "The Operations of Surgery," p. 793; 1891.
[4] "The Science and Art of Surgery," vol. i., p. 881; 10th edition, 1895.

siders that "the only way of clearing up the uncertainty is to enlarge the wound, or to open the abdomen in the middle line, and to examine the abdominal viscera. This treatment may seem severe, but experience has taught us that an exploratory incision into the abdomen, if undertaken with proper precautions, is practically free from danger; and, on the other hand, if we wait till the injury to the intestine becomes evident by the commencement of septic peritonitis, the case is altogether hopeless." Quotations to the same effect, advocating laparatomy at the earliest possible moment in the treatment of these injuries, might be multiplied to almost any extent, but enough has been put forward in support of the modern view of the advantages of early operation to show that this is now the view held by the highest authorities. Greig Smith, Senn, of Milwaukee, Chauvel, of the Val de Grâce, as well as many others, strongly uphold it. Delorme admits its correctness in principle, but alludes to the difficulties which must be expected in the performance of these operations in warfare, and considers that only under exceptional circumstances can they be undertaken.

The percentage of deaths in these cases, even when treated by laparotomy, is high, principally in consequence of the duration of the operation, the increase of shock, and the difficulty experienced in thoroughly cleansing the soiled peritoneum; but it is less than that which follows the expectant method.

The time during which laparatomy can be done with the best chance of success is short: after twelve hours the probabilities are against recovery, and after twenty-four or forty-eight hours it is almost useless to attempt it When peritonitis has fully developed, the apertures in the intestines may not be found, or, if found, it may be impossible to lose them by suture, and, besides, the condition of the patient at this time will be one which must almost preclude recovery from any operation. Coley's statistics give a death-rate of 35.8 per cent. for 39 cases operated on in the first twelve hours, and 77.2 per cent. for 22 cases done at a later period. If we admit that all

penetrating gunshots of the abdomen require operation, no argument is needed to show that the sooner it is performed the better; the figures given above endorse this view. Statistics show a smaller death-rate from abdominal wounds when laparotomy has been done, than when expectant treatment has been employed; it may not be very much smaller, but the latter method means abandoning the patient to peritonitis and death, and the former adds nothing to the gravity of the case.

When the situation of the wound in the parietes, and perhaps other signs—hæmaturia, for instance—suggests laceration of the solid viscera within the abdomen, laparotomy is as strongly indicated as it is in the cases just referred to. Dangerous hæmorrhage seldom results from gunshots of the hollow viscera alone; but when the liver, kidney, or spleen is implicated, hæmorrhage may be very profuse. If large vessels in these organs are torn, death will rapidly ensue; but if only the smaller ones are severed, the bleeding will probably persist until mechanical means are employed for its arrest, or the patient dies. Here also, then, laparotomy is the only method which renders the special treatment possible.

Certain circumstances may be considered as contra-indications to operation, and they, for the most part, depend on the general contitutional condition of the patient. Profound shock and collapse are among these. If it can be avoided, no patient should be operated on during the presence of the primary shock of an injury, and least of all should an operation on the contents of the abdomen be performed, for such operations are themselves causes of marked shock and collapse. Collapse due to hæmorrhage will, of course, form an exception to this rule, for the hæmorrhage will continue and the collapse can only change into coma and death if the usual means are not adopted to control it. A long interval having elapsed since the receipt of the injury is also a contra-indication to operation: here diffuse septic peritonitis will have set in, and the desired ends cannot be attained; but, as MacCormac says, a moderate amount of peritonitis should not be so consid-

ered. Then, again, in cases of abdominal wounds produced by large projectiles or their fragments, and when the spinal cord has been injured, laparotomy can hardly be expected to give satisfactory results.

It is, unfortunately, true that laparotomy for suture and resection of intestine is a delicate operation, and one that requires much time for its performance, time which, as has already been suggested, might possibly, according to the opinions of some surgeons, be more usefully expended in attending to patients less seriously injured. No doubt, if the number of wounded in a field hospital be large, and if many of them be injured in this region, it may be impossbible to devote sufficient time to them all. But if the opposite conditions obtain—and abdominal cases only average from 3 to 4 per cent. of the total wounded who come under treatment—a good deal should be possible for men injured in this way. The practice hitherto pursued of leaving men wounded in the abdomen to die, without an effort being made to repair lesions which, without aid, are almost necessarily fatal, must be abandoned, and military surgeons must in future be as skilful and as willing in the performance of laparotomies in war hospitals as are their colleagues in civil life, when the indications for treatment clearly point to the necessity for such interference.

Considerable dexterity is required in suturing an aperture in the intestine or in resecting a portion of the tube, in order to produce a thoroughly water-tight seam, and no surgeon is justified in opening the abdomen for these purposes unless he has availed himself of numerous opportunities of practising the operation on the dead body, and, if possible, of proving the efficacy of his procedures on living animals. The difficulties at first appear to be very great; but "practice makes perfect" in this as in other matters requiring accuracy and skill.

The actual procedures to be carried out in the treatment of a case of abdominal wound, on arrival at a place where detailed treatment is possible, may be fairly well inferred from what has been already stated. If shock and collapse are profound and well marked, *and if they be not*

due to internal hæmorrhage, the first thing to be attended to will be the patient's recovery from this condition, by the application of the means usual under these circumstances—external warmth, friction, and stimulation. For the latter purpose, the subcutaneous injection of ether is probably more effective and more judicious than the administration of diffusible stimulants by the mouth, which will be contra-indicated by the vomiting, and because the less food or fluid taken into the stomach for the first twenty-four hours in these cases the better.

If the collapse be the result of internal hæmorrhage, the patient will be unlikely to respond to stimulation, and some further risk must be incurred by operating while more or less shock and collapse are present. In this connection, too, it may be remembered that, once the bleeding has been controlled, the use of very hot fluids (110° F.) for the flushing out of the peritoneal cavity may be expected to have most desirable effects towards bringing on reaction. That the collapse is due to internal hæmorrhage is evidenced by the exsanguined and blanched condition of the skin and mucous membranes, extreme restlessness, sighing respirations, rapidity and weakness or absence of the pulse, and dulness on percussion in the flanks.

When reaction has set in, and the patient has recovered sufficiently to be able to bear an operation, the wound should be explored by means of the finger, for the purpose of diagnosis as to penetration. The surrounding skin should be shaved, if necessary, and well washed and disinfected. Everything which touches the wound or enters the abdomen must be absolutely aseptic, for probably in no class of cases are antiseptic precautions of such importance.

Wounds by small-bore bullets will usually have to be slightly enlarged for exploration. Incisions of about one-half or three-quarters of an inch in length should be made upwards and downwards from the edge of the bullet aperture, and down to the peritoneum; then by careful inspection and the insertion of the finger a definite diagnosis of penetration or otherwise may be made, and if this ques-

tion is settled in the affirmative, the operation should be proceeded with at once.

The operation of laparotomy when performed for gunshot wounds, differs in no way from that required for injuries from other causes, except in the number of intestinal and other visceral wounds which may require treatment. I may therefore refer the reader to the standard works on operative surgery for the precise details of the required procedures, and only allude to the subject here in general terms.

The incision should be in the median line, except when the situation of the external wound points to implication of the right lobe of the liver; in this case enlargement of the bullet aperture will probably be more convenient, and give better access to the injured part. An incision through the inner edge of one of the recti muscles has been recommended as giving a stronger cicatrix and one less liable to permit of ventral hernia; but, on the whole, that in the middle line is admitted by most surgeons to give satisfactory results. Still, no law of mere custom should be allowed to prevail in this matter, and the incision may be made in any position which seems to the operator best calculated to afford means to the desired end.

No estimation of the number of intestinal injuries which will require treatment can be formed before the abdomen is opened: they may vary from one or two to a dozen, or even more; and they may all be close together, or some may be widely separated from others. The more nearly the bullet track corresponds to the antero-posterior diameter of the abdominal cavity, the fewer are likely to be the number of perforations; and, on the other hand, the greater will be their number, as the bullet track is oblique in direction, and as it more nearly approaches the line of the transverse diameter. In these cases one must always expect to have many apertures to suture, and perhaps more than one resection to perform.

Several methods of applying sutures to the intestine have been devised, and reference may be made to them in any work on operative surgery, but, practically, Lembert's

plan is the one almost universally used. The continuous suture is seldom to be recommended for intestinal work, for, though it may be more rapidly applied than Lembert's, it is more liable to loosen and permit of leakage. The usual directions given for the insertion of Lembert's suture are that it should take up the serous and muscular coats without perforating the mucous coat; but the ideal Lembert suture should include, not only the serous and muscular coats, but it should take up a fibre or two of the strong, fibrous, submucous layer as well, as this adds very considerably to the strength and durability of the stitch.

The best material for intestinal suture is the finest kind of China-silk thread which has been boiled in 1–20 carbolic lotion for two hours on four or five days, with an interval of a day or two between each boiling, and then kept in absolute alcohol. The milliner's common round needle is the best to use, and Greig Smith recommends that its point should not be *too sharp*, as this facilitates the catching up of the submucous layer.

Single perforations of the intestine may be closed with Lembert's sutures, if the loss of substance is not so great that closing them will cause serious diminution of the lumen of the gut. A loss of substance in the intestinal wall so extensive that closing it by simple suturing will produce a considerable reduction in the calibre of the bowel, is a condition which will frequently necessitate a complete resection. But if the plan recommended by Heineke in 1886, and by Mikulicz in 1887, in the treatment of non-malignant stricture of the pylorus be employed, and large apertures produced in the intestine by gunshot be sutured by bringing their edges together transversely to the length of the gut instead of parallel to its longitudinal direction, by which means its diameter at the site of the wound will be increased rather than diminished, which is the principle of the operation on the pylorus above referred to, complete resections may sometimes be avoided. Fig. 76, A, B, and C, will explain this method. It is merely another application of the principle of an operation which has been used in cases of simple stricture of the pylorus; and, as the end

desired to be attained is the same in both cases—viz., the retention, as near as may be, of the normal calibre of the tube—it may prove to be of use.

If, on opening the abdomen, the surgeon finds that he is able to repair all the intestinal injuries by merely suturing together the edges of the perforations, the operation will be much simplified, its duration curtailed, and

A

B

C

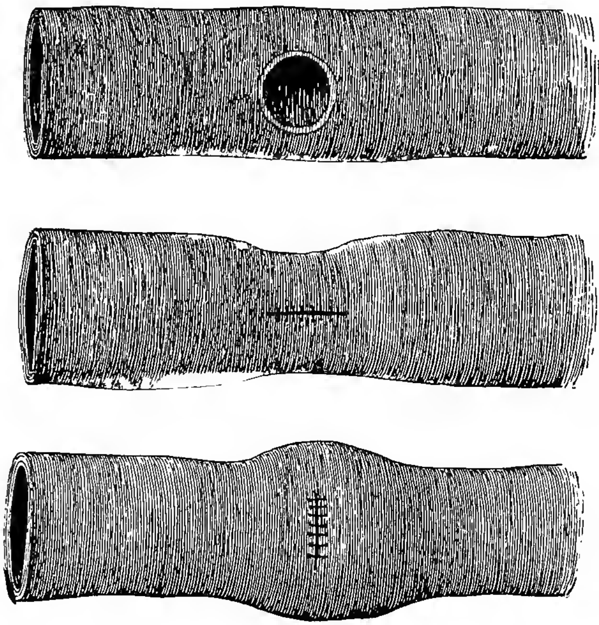


FIG. 76.

Method of suturing a perforation in intestine.

the prognosis in the case rendered more favourable, no matter how many of these small operations have to be done. But not all cases, nor indeed the majority of them, will be of this simple character. Many of them, in consequence of the extent and positions of the lesions, will require complete excisions of portions of the tube for their repair, and some of them may necessitate more than one excision. These latter are the most dangerous cases, owing to the time they take and the shock due to them, as

well as to the increased probability of failure to secure a thoroughly water-tight seam in such extensive lines of suturing.

The cases which require resection are—(1) those in which the perforation includes the mesenteric border of the gut, because in these the principal source of blood supply is cut off, and the section of the bowel implicated is likely to slough and thus permit of extravasation; (2) those in which there are two or more perforations quite close together; and (3) those in which the loss of substance and general destruction done to the tube is such that it is found impossible to repair it by simple suturing without dangerous diminution of its calibre.

The position in which the gut is divided for resection is of great importance: in order to secure an ample blood supply, the sites for the incisions through the intestine should be so selected as to be near the points at which a mesenteric arterial branch comes off, and this although it may possibly necessitate the removal of a slightly larger segment of intestine. When the removal of a V-shaped portion of the tube alone, not interfering with the mesentery, is sufficient, this should be done, as section through the mesenteric border greatly increases the difficulties of the operation; but this will only happen when the mesenteric border is itself uninjured. In cases where several perforations existed close together, Parkes found it better to do a resection including them all, even when this involved the removal of eight or ten inches of the bowel; and when the injuries were far apart, but so severe as to require resections, separate resections had to be done for each.

Parkes also found that the treatment of the mesenteric border of the intestines was always difficult, and that leakage at this point occurred more frequently than at any other. To overcome this he recommends that three sutures be inserted at this point, and that great care should be taken to include the muscular coat.

When a large segment of intestine has to be excised, a V-shaped portion of the corresponding mesentery should

be removed, its vessels all ligatured, and the cut edges brought together by interrupted sutures. Greig Smith does not remove any portion of mesentery: he ligatures the cut vessels where its edge has been separated from the intestine, runs a purse-string stitch through its margin, and attaches it to the cut ends of the intestine when these are sutured together, and this plan is certainly suitable when the segment of tube removed is short.

The sutures used in intestinal work should be placed in the proportion of about ten to the inch, and Parkes points out the danger of drawing them too tightly, "as this leads to the death of the applied edges, and failure from leakage: they should be drawn only sufficiently close to bring the surfaces fairly in contact.

The question of the necessity of examining and inspecting the intestine from end to end for the discovery of lesions is one on which there is some difference of opinion amongst the greatest authorities. If only one perforation be overlooked, it will almost certainly prove the cause of a fatal issue. On the other hand, this complete examination requires a long time, and adds enormously to the shock to the patient, thus endangering his life in another way. MacCormac considers that the bowel should be examined from the ileo-cæcal valve upwards and downwards to the stomach and to the rectum; Nancrede, Senn, and many others hold similar views. M'Graw, of Detroit, suggests that the length of the operation may be reduced "by strictly limiting the examination of the viscera to such of them as may have been in the course of the ball." Greig Smith says,[1] in this connection: "A systematic examination of all the viscera *which lie in or near the track* of the ball is to be carried out."

The numerous cases which have proved fatal in consequence of perforations being overlooked, are, no doubt, powerful arguments in favour of the complete examination; but the necessity for this procedure will partly depend on the degree of obliquity with which the bullet has traversed the cavity, and partly on whether or not it is

[1] "Abdominal Surgery," by J. Greig Smith.

possible to ascertain the actual track it has followed. Then, again, the general condition of the patient must be taken into consideration. Theoretically, complete examination is most desirable; but if the patient be not in a condition to bear a very prolonged operation, it may be necessary to omit it, and take for granted that viscera which lie apparently outside the course of the bullet are uninjured. In fact, each case must be considered and treated in accordance with the conditions it presents, while, at the same time, the danger of leaving a perforation, however small, unsecured, is kept prominently in view.

The particular operation which is selected, and the method of it, must also be left to the individual choice of the surgeon; he will, no doubt, select those procedures in which he knows himself to be most skilful, and on the practice of which he has spent most time. Without experimental work he had better leave intestinal operations alone.

One method of performing excision of a portion of the intestine I may refer to more particularly, as it is not so well known as it deserves to be in this country. Erichsen and Greig Smith mention it in their last editions. It is that of Professor H. W. Maunsell.[1] This operation differs from all others in that the sutures are passed through all the coats of the intestine, and it is applicable to all other kinds of operations on the intestinal tract as well as to that of excision. The principle on which it depends consists in invaginating the resected ends of the gut through a longitudinal slit in the convex surface opposite the mesenteric border, and there suturing them together. Reference to the accompanying figures will render the comprehension of the procedures easy. Fig. 77 shows the incisions through bowel and mesentery. The edges of the mesentery are brought together by interrupted sutures, as shown in fig. 78, ligatures having been previously applied to all bleeding vessels. Two silk sutures, which are left long, are then inserted, one to bring the mesenteric borders of the gut together, and the other to unite the cut ends at

[1] See *American Journal of Medical Sciences*, March 1892.

the opposite point in the circumference (fig. 79). These sutures pass through all the coats of the intestine, and the former takes up both edges of the mesentery as well. A longitudinal incision is made in the upper convex surface of either portion of the intestine, about one inch from the line of section, and one and a half inches long, in the manner shown in fig. 80. The two long "traction sutures" are passed out through this incision (A, B, fig. 81), and, when drawn upon, cause the cut ends of the bowel to appear at A, B, fig. 81, as shown in fig. 82. The re-

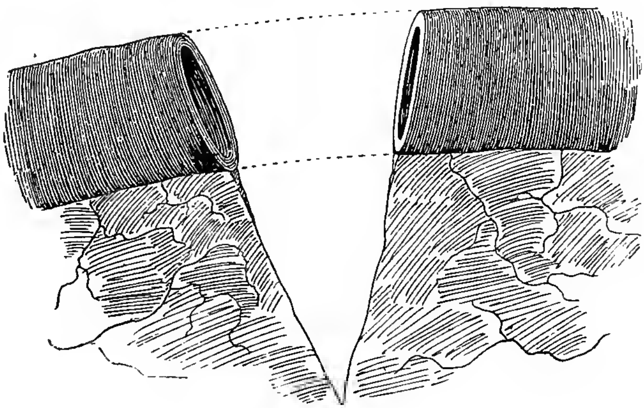


FIG. 77.

sected edges of bowel are now in position to be sutured, the two serous layers being in contact, as shown in fig. 83. The needle may either be passed completely across the lumen of the gut, as shown in fig. 82, and the suture drawn out in the centre and cut, thus forming two sutures, or it may be inserted so as to make a single stitch: the latter is the quicker method. The needle should traverse all the coats of both ends of the intestine, and at about a quarter of an inch from the ends. When as many sutures as may be considered necessary have been put in and tied, the long traction sutures are cut away, and the invagination reduced, but more by manipulation than traction, and the longitudinal incision closed by Lembert's suture (fig. 84). All the permanent sutures applied to the intestine in

Maunsell's operation are of strong horse-hair. A silk suture applied as Maunsell's are, through all the coats of the intestine, would be certain to cause the escape of septic

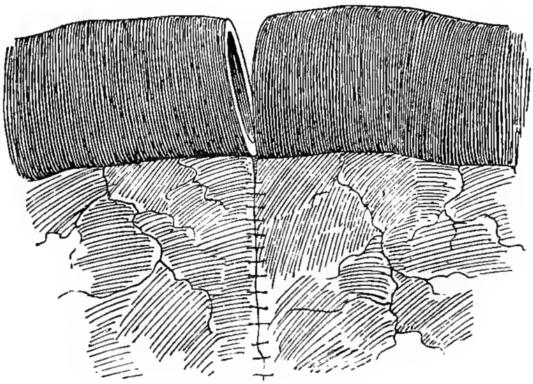


FIG. 78.

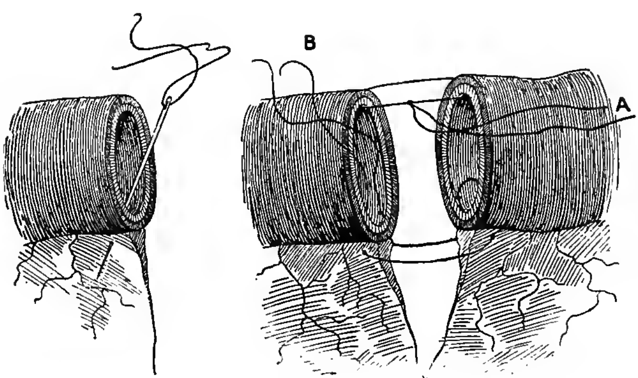


FIG. 79.

matter by capillary attraction; and in other operations where silk sutures on Lembert's plan are used, the accidental passage of one of them through the mucous coat is frequently sufficient to make all the difference between failure and success. Horse-hair has not this objection: it does not become saturated with septic material in its passage through the lumen of the gut, and a single strand does not permit of capillary action.

Maunsell's operation is more easily and rapidly performed than any other method of circular enterorraphy; probably the employment of Murphy's button is the only means which excels it in the facility and quickness with

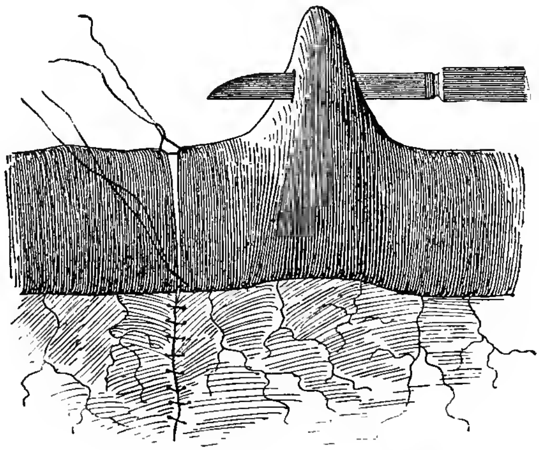


FIG. 80.

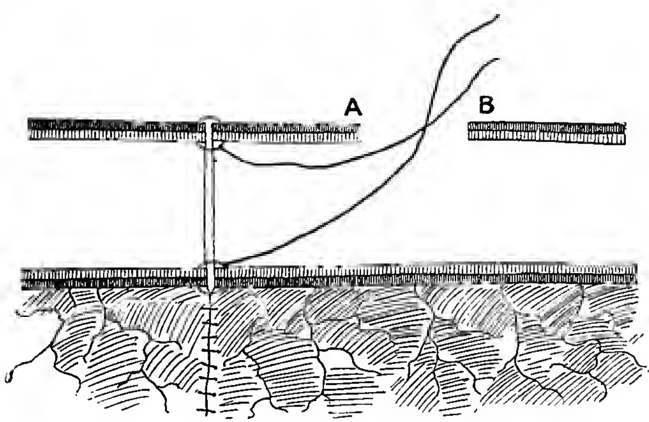


FIG. 81.

which the same end can be obtained. The objections which have been urged against it, are the additional incision in the bowel, and the danger of leakage at the points of suture, because these pass through the mucous coats. But these disadvantages must be only theoretical, for ten

out of fifteen reported cases in which it has been adopted recovered. Successful operations have been performed in

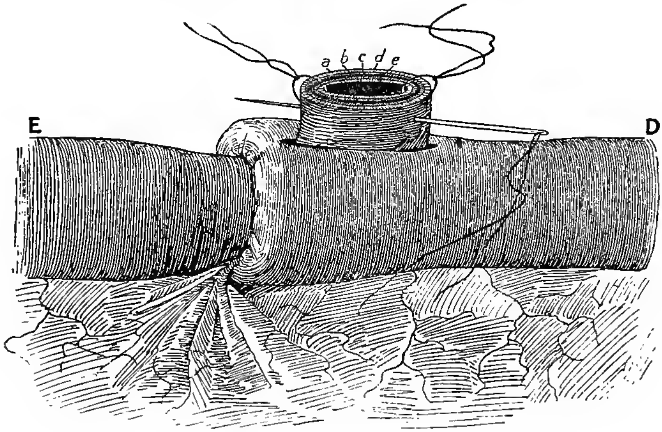


FIG. 82 (see fig. 83).

a—Mucous membrane of E segment.
b—Serous membrane of E segment.
c—Line of contact of two serous membranes.
d—Serous membrane of D segment.
e—Mucous membrane of D segment

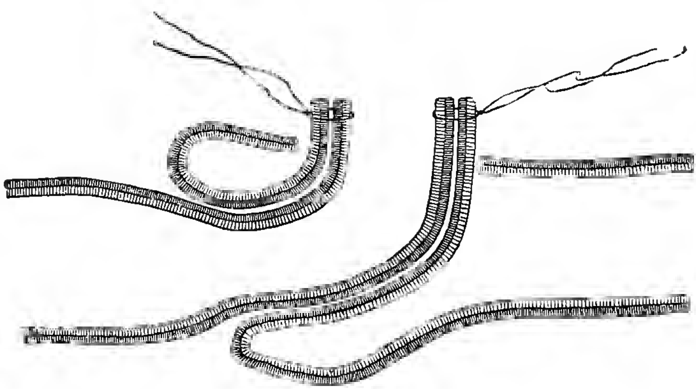


FIG. 83.

this country by Stanley Boyd, Harrison Cripps, Keetley, Bidwell, Watson Cheyne, and Rose, and by others in America and on the Continent.

In a large number of Parkes's fatal cases it was found

that leakage had occurred at the mesenteric border. This is the point at which effective suturing is most difficult, and it is always advisable to put in more than one stitch at this situation. Care must be taken, when uniting the cut ends at this point, to close the triangular space left by the separation of the two layers of mesentery at the point of attachment of the latter to the intestine.[1] This space contains the arteries, loops from which pass on to supply the intestinal wall, and failure of close approximation at this point is liable to be followed by a small area of gangrene,

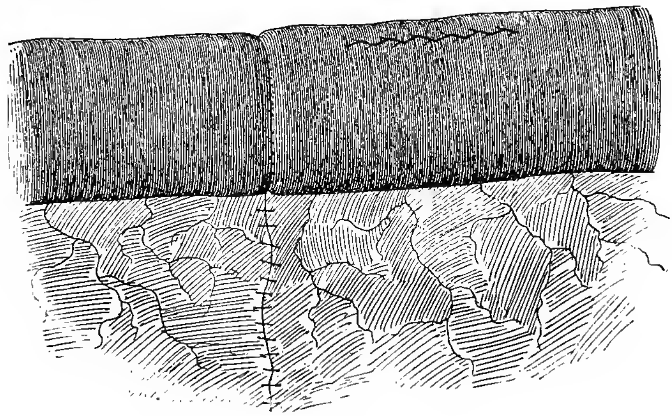


FIG 84.

resulting in an opening into the tube and the escape of fæcal matter. Parkes recommends putting three sutures in the mesenteric edge.

Immediately the bowel is cut across, its calibre lessens, and after a short time the mucous membrane protrudes all round the cut edge, interfering considerably with the process of suturing. On no account, however, must it be removed; in all cases in which this was done in Parkes's experiments, union failed from the stitches giving way. Tying them too tightly is another cause of stitches not holding; the edges to be united should be drawn just in contact, and no more.

[1] See Mr. Anderson's note upon this subject, and diagram, p. 80, of Sir William MacCormac's "Abdominal Section," 1887.

Wounds of the omentum require special attention. Small perforations not implicating vessels should have their edges brought together by continuous or interrupted sutures; but where large vessels are wounded, almost the whole membrane may become infiltrated with blood-clot which cannot be removed without tearing it to pieces. So much of it as is damaged in this way, should be removed by ligaturing it off in one or more sections with aseptic silk, and cutting it away below the ligatures.

When the abdomen is opened for the treatment of a gunshot wound, the first thing to do will be to remove blood-clots, and search for bleeding points, if anything like copious hæmorrhage has been taking place. The vessels should all be clipped with pressure forceps and ligatured. The abdominal cavity should then be flushed out with boracic lotion, or with boiled water, at a temperature between 105° and 110° F., and this should be continued, more or less uninterruptedly, during the whole operation. The best nozzle for the tube of the irrigator is a piece of glass tubing, 10 inches long and of ½ inch diameter. The effect of hot irrigation in reducing and preventing shock has been already alluded to. Then the visceral lesions should be sought for, and repaired in the order in which they are discovered, a little iodoform powder being rubbed into each line of suture.

When all the operative work has been completed, a final washing out and drying of the abdomen should be performed. This has been termed the "toilet of the peritoneum." It cannot be too strongly insisted upon that the greatest gentleness must be used in these manipulations—indeed on all occasions when the peritoneal surface is being handled. Every scrape and injury it receives by reckless methods of drying and flushing tends to lessen its power of opposing the action of micro-organisms, and to permit the latter to develop those toxic products which are the immediate causes of death in cases of peritonitis. Sponges should not be used for removing fluids or extravasated matter from the abdominal cavity. Pledgets of aseptic wool, which have been soaked for many hours in 1–20 car-

bolic lotion, and then washed in boiled water or weak sublimate solution, and wrung dry, may be used without fear; while sponges may not always be free from danger. Extravasated fæcal matter should be removed by flushing with hot sterile fluids, while the coils of intestine are being moved from side to side with the hand, rather than by rubbing with wool or sponges. But whatever means are used, they should be so lightly applied as to ensure that no injury is caused to the surface of the serous membrane.

The use or the omission of a drainage tube in these cases will depend on the condition found in the abdomen. If the operation has been performed early, and if there be no reason to expect further extravasation, a drain will not be required. But if, on the other hand, peritonitis has had time to develop, a Keith's tube or a gauze drain should be passed from the lower end of the wound into the deepest part of the pelvis; or, if the incision be too high up, a separate aperture may be made for it below the umbilicus.

FIG. 85.
Greig Smith's Needle-holder

The parietal incision may be closed either by suturing the deeper structures layer by layer with buried silk sutures, and the skin with silk-worm gut, or the needle may be passed through the whole thickness of the abdominal wall half an inch from the incision, and the skin brought together by separate sutures close to its edges; but in either method the edges of the peritoneum must be included. In the latter method of closing the incision, silk-worm gut should be used, and long Hagedorn's needles fixed in Mr. Greig Smith's holder (fig. 85) or some similar instrument are most convenient.

The treatment of abdominal wounds by the formation of an artificial anus should only be resorted to as a last resource, when the general constitutional condition of the patient is so critical that any more prolonged procedures

cannot be borne. It is bad surgery even if it succeed; the patient's life, while the abnormal opening continues, is usually one of extreme wretchedness, and the mortality following enterectomy, which is the operation now adopted for its cure, is, according to Makins, as high as 38 per cent.

If, on opening the abdomen, such a condition of septic peritonitis is found that the intestinal lesions cannot be detected and repaired, nothing can be done but to wash out the cavity as thoroughly as possible and put in a drainage tube; and cases of this kind form exceptions to the rule now almost universally admitted of withholding opium in the treatment of abdominal wounds, because the arguments in its favour do not hold good under the circumstances. The use of opium for these cases may lessen further extravasation, and it cannot mask dangerous symptoms, because the worst symptoms are already present. This subject will be again referred to.

In dressing the abdominal incision, it should first be thickly dusted over with iodoform and finely powdered boracic acid, and then covered with a pad of iodoform or double-cyanide gauze, over which a large quantity of aseptic wool should be placed, the whole dressing being fixed with a wide binder which exerts a gentle pressure. In the absence of symptoms requiring its removal, the dressing should not be interfered with for eight days. If a drainage tube is used, the outer end of it should be made to project through the deeper layers of the dressing, and covered with a separate pad of wool, so that any blood or serum which collects in the pelvis may be sucked out by means of a glass syringe to which a piece of rubber tubing has been attached, as is done in cases of operation on the uterus and its appendages.

If septic peritonitis supervenes in a case treated by laparotomy, the adhesions formed in the lower part of the incision should be broken down, the abdominal cavity well flushed out with hot boracic lotion, and a glass drainage tube put in, the irrigation being repeated as often as may be considered necessary. A glass funnel with a rubber tube and a glass nozzle are the best means of performing

irrigation; and when it is desired to remove from the abdominal cavity the fluid which has been used, lowering the funnel to the level of the floor will cause it to syphon off if the tube has not been allowed to become empty. Greig Smith points out that too great care to remove all the irrigation solution need not be taken, as if a little be allowed to remain it will tend to prevent adhesions forming and septic processes being carried on as actively as might otherwise be the case.

The Dieting of patients injured in the abdomen is a very important matter in their after-treatment, both in cases of contusion where visceral lesion is possible, and in cases of penetrating wounds, as well as in those in which abdominal sections have been performed.

Until quite recent times it was admitted by the best surgeons that no food, liquid or otherwise, should be allowed by the mouth during the first twenty-four, or, better still, forty-eight hours, feeding by the rectum by means of nutrient suppositories and enemata of peptonised milk being substituted. This rule has, possibly, been too rigidly adhered to, and latterly we find, with increasing frequency, cases reported in the journals where feeding by the mouth as well as by the rectum has been carried out from the first with the best results. Professor A. E. Barker, of University College, reports seven cases of abdominal section for perforated gastric ulcer in the *Lancet* of December 1896, in which this was done, and other surgeons follow a similar plan after operations on the other organs in the abdomen.

The more profound the degree of shock after laparotomy the more urgent is the need for nourishment in whatever manner it can be most rapidly assimilated, and it is particularly in obviating the effects of this condition that Professor Barker "places great reliance on feeding by the mouth as soon as the patient has recovered from the anæsthetic." If vomiting be present, of course this plan cannot be attempted; but in the absence of this symptom, and when feeding by the mouth is considered necessary in addition to that by the rectum, which is always required, teaspoonful doses of white of egg with water and a little

brandy may be given every two hours,[1] the quantity being cautiously increased from day to day. Later, Brand's essence, chicken broth, milk, and such-like foods may be added, but only in small quantities, and at intervals of at least two hours. Nutrient enemata of peptonised liquid foods or suppositories should also be administered every four hours, and occasionally small enemata of hot water. If great thirst be complained of—and this is frequently a distressing symptom—it may be best allayed by means of the warm-water enemata already alluded to, and by giving teaspoonfuls of hot (not tepid) water at intervals. Giving ice to suck is not nearly so effective against thirst, and large quantities of water may be passed into the stomach in this way, causing or encouraging vomiting. After the lapse of a week or ten days the more ordinary diet may be slowly resumed, any ill effects being carefully watched for.

The Use of Opium in Abdominal Cases.—Up to comparatively recent times, abdominal injuries, and especially those suspected to be complicated by visceral lesions, were all treated by rest and opium. Under the circumstances nothing better could have been done; for as long as peritonitis was supposed not to be amenable to local treatment, and while symptoms of extravasation into the peritoneal cavity did not suggest operative interference, the administration of opium was, in some ways, the best treatment to adopt. It tended to diminish the extravasation, and it ensured, at all events, a euthanasia. Now all this is changed.

Probably no greater revolution has occurred in therapeutics than has taken place during the last few years in the use of opium in abdominal cases. Formerly all cases were supposed to require it; now it may almost be said that no case should get it. Once surgeons began to recognise the power of the peritoneum as an absorbing, and therefore as an eliminating organ, and learnt its capability of dealing with bacteria and their septic products, it became evident that the administration of opium in these cases was opposed to common sense, because opium, of all drugs, has

[1] Barker.

the greatest influence in restraining the processes of absorption and elimination.

For another reason, too, the use of opium is contraindicated. The very ease and comfort which it ensures to the patient are often its worst effects; for these are secured only at the expense of hiding from the observation of the surgeon those signs of the fatal changes which may be going on within, on which alone he can base his conclusion as to the necessity of interfering by operation, the only means of rescuing the patient from a speedy death.

Cases of abdominal injury must be divided into two categories as regards their suitability for the administration of opium. In the first class would be placed those in which there is no external wound, but in which visceral lesion, although there may be no evidence of it, is nevertheless possible; and cases, with or without external wound, in which, although visceral lesion may be suspected, yet there are no signs pointing to a necessity for immediate operation. In these cases the setting in of some symptoms of internal injury must be awaited, and *no* opium should be given, lest their occurrence should be masked by its quieting and narcotic effects.

The second class would comprise those in which laparotomy has been performed, and the intestine sutured or resected. In the treatment of these latter cases, one plausible reason for the use of opium may be put forward, that it tends to arrest the peristaltic action, and so places the injured part in that condition of absolute rest so necessary for prompt repair. But even for this purpose the good effect of opium may be doubtful; for arrest of the natural movement of the bowel may set up such a degree of tension from an accumulation of flatus at the site of suturing that the whole advantage of the operation may be lost. Moreover, the absorbing power of the peritoneum may be as much required in these cases as in the others, and opium lessens or prevents it. Greig Smith says, in this connection: "If opium is to be recommended anywhere in abdominal surgery, it should be in such cases as these, which are frequently attended with considerable mental

disturbance." Jacobson recommends morphia injections with one-sixtieth grain of atropine; Erichsen, "the free administration of opium." Delorme suggests successive doses of opium or of morphine, and Chauvel and Nimier give similar advice. Frederick Treves[1] says: "Morphia will probably have to be given; the less the better, so long as peristaltic action is stopped."

Lawson Tait is one of the most strenuous opponents of the use of opium in the after-treatment of cases in which abdominal sections have been performed.[2] Indeed, to him is mainly due the credit for our present knowledge of the unsatisfactory effects of the drug, as well as for the quite opposite line of treatment now adopted in place of it. Much fault has been found with Mr. Tait for claiming to have "cured traumatic peritonitis" by the use of saline purgatives and turpentine enemata; those who disagreed with him asserting, naturally enough, that, as the cases so treated got well and no opportunity for post-mortem examination occurred, they might not have been cases of peritonitis at all. This he had to admit was a sound argument, as it fell in with his own writings on the signs of peritonitis, and his reply, in a word, was to this effect. Certain symptoms may arise within a few hours or a few days after the performance of an abdominal section, the most important of which are bilious vomiting, abdominal distension, and failure of the bowels to pass either fæcal matter or flatus. If opium has not been given, and if these symptoms are immediately treated by turpentine enemata and Seidlitz powders, with the effect of causing the bowels to act, they will disappear and the patient will recover; if this treatment be not adopted and opium be used instead, the patient will die, and at the post-mortem the usual signs of peritonitis will be found. These conclusions are drawn from the observation of considerably over 1,000 cases of traumatic peritonitis. "Years ago," Mr. Tait writes, "I was driven to the determination to discontinue absolutely the use of opium by the mouth after

[1] "A Manual of Operative Surgery."
[2] *British Medical Journal*, Nov. 1892.

abdominal operations, for two reasons: first, its action on the intestines is most certainly to modify, and even suspend, vermicular movement; and secondly, it masks the real condition of the patient. One dose of morphine, given under the skin immediately after the operation, is all that my patients ever get, and the great bulk of them do not get that."

I have had many opportunities of observing the good effects of salines and enemata in abdominal cases since Tait suggested them, and of seeing the patient's rapid change from the condition causing great anxiety to one of almost complete safety when an action of the bowels has been secured, and I am convinced that this, rather than the administration of opium, is the line to take for the prevention of peritonitis and for the treatment of the early stages of the complication. In cases, however, in which resection has been performed, purgatives by the mouth must be used with caution, and not until good union may be supposed to have taken place, probably not earlier than thirty-six hours. When the lower portions of the large intestine have been operated on, enemata should be avoided for a similar time, and even then they should be used with great gentleness and care.

The number of mechanical contrivances which have been invented for the purposes of facilitating the operation of suturing intestine, in both end-to-end and lateral anastomosis, is almost unlimited. All kinds of devices have been proposed and tried; some are very useful and some quite the reverse. Cylinders of trachea, decalcified bone plates, plugs of tallow, dough, or turnip, plates of wood, bobbins of many different materials, clamps, &c., all have been tried, sometimes with success and sometimes with the opposite result. Senn's decalcified bone plates, and bobbins of the same substance, have probably been found the most useful; but the same objections may be brought forward against them all—the length of time expended in their application, and the faultiness in the seam sometimes obtained by their use.

Almost, if not quite, the newest invention of this kind

is Murphy's button. Treves's report[1] of several cases in which he used it, is distinctly favourable to the instrument. It is suitable for all kinds of cases in which one portion of intestine has to be joined to another, and it can be fixed in a few minutes. Its one fault — and it is, theoretically at all events, a serious one—is that it may fall into the proximal end of the bowel and be retained, though practically no inconvenience had, when Treves wrote, been experienced from this accident. Even when it passes into the distal end it may still be retained, probably in consequence of failure to pass the ileo-cæcal valve; but in neither case has it caused obstruction. The button has nearly always been passed when used on the large intestine. A much more extended trial of this contrivance will be required before any really valuable conclusions can be arrived at as to its good and bad qualities, especially the latter, and as to how to overcome them if this be possible. It certainly promises to be of use. Its application considerably shortens the duration of the operation of intestinal anastomosis, the shock of which is therefore lessened, and it produces a satisfactory union. How far its retention within the intestinal tract, either for a long time or permanently, may prove a danger, has yet to be ascertained.

What has been written in the foregoing pages on the subject of operation on the intestine has only been intended as a discussion, in a general way, of this important matter, without which the subject would have been, I think, incompletely dealt with. For a detailed description of the procedures included under this head, reference should be made to works more particularly devoted to operative surgery, such as those of Senn, Sir William MacCormac, Treves, Jacobson, Greig Smith, &c., as well as to the numerous accounts of particular cases in the medical journals. Preparedness, self-reliance, and great manual skill are necessary for their satisfactory performance, and these, as already mentioned, are only to be gained by long practice

[1] *Lancet*, 4th January 1896. See also papers by J. B. Murphy, *Lancet*, September 1894, and by Mitchell Banks, *British Medical Journal*, February 1895.

on the dead body and on animals. Without this the surgeon may be compelled to see patients die unrelieved, because he knows that, at his hands, operation would be unjustifiable, and the knowledge of the bare possibility of such a misfortune should be a sufficient incentive to induce him to take the only means of avoiding it with certainty.

Wounds of Special Organs within the Abdomen.

Stomach.—Otis records 79 cases of wound of this viscus as having occurred during the American War, with a mortality of 79.9 per cent. But regarding this very satisfactory result, considering the treatment then in vogue, he points out that the histories of these cases are so badly given that the evidence of stomach wound is unreliable in most of them, and he is of opinion that the real death-rate in these cases more nearly approached 99 per cent. than it did to that shown in the official returns. Of the 79 cases stated to be wounds of the stomach, 64 were from gunshot penetration, with only 1 undoubted recovery where the diagnosis had been made with certainty. In the reports of the Franco-German War 16 cases of gunshot wound of the stomach are reported, with 12 deaths, or 75 per cent.[1]

The prognosis is extremely grave in these cases; the large majority die on the field from shock and hæmorrhage, and of those who have hitherto come under treatment, very few have survived. Sir William MacCormac, Delorme, and others refer to some cases of recovery; but recovery has, up to the present, been quite exceptional.

An interesting case of undoubted wound of the stomach in which recovery had taken place was admitted at Netley in 1891; the following is a short note of the history of the case. On 9th February 1891, Private J——, of 1st East Lancashire Regiment, was employed in the armourer's shop in assisting to test a rifle, which was screwed into a rest for the purpose. He was standing in front of the rifle, and at about six inches from the muzzle, when it accidentally exploded. The rifle was loaded with a blank

[1] Delorme.

cartridge, which was covered with a card-board wad and a wax plug. The accident happened about ten minutes after the man had finished a full breakfast. The man was carried to hospital; the wound was well cleaned, and dressed with iodoform gauze and alembroth wool, and the patient placed under the influence of morphine. An hour after the receipt of the injury he vomited, first some of the powder, and then the card-board wad and the wax plug, but no blood. He was fed for some days by means of enemata, and the wound had healed in nine weeks. On the man's arrival at Netley, the cicatrix was found situated over the region of the stomach, a little to the left of the middle line. He was fairly well nourished, but complained of pain soon after food, due, probably, to dragging on attachments between the stomach and the abdominal wall: a curious case, certainly, but hardly one affording indications for any general line of treatment on similar occasions.

The Symptoms of wound of the stomach are shock, extreme pain, hæmatemesis, and the escape of the contents of the organ by the external wound, taken in conjunction with the position of the aperture in the parietes. Shock is usually even more profound than it is in cases of wound of any other part of the alimentary tract. Pain also is usually of great severity. Hæmatemesis may or may not occur; and, morever, it may be present when the stomach has not been wounded, in consequence of simple contusion of the stomach or of injury to the upper part of the small intestine. The only certain sign of wound of the stomach is the outward escape of its contents, and this but seldom occurs. Usually, therefore, the data on which diagnosis must depend will be the relation between the positions of the external wound and of the stomach, profound shock, and severe pain. Hæmorrhage to any great extent seldom takes place outwardly; but when either curvature is implicated, profuse internal hæmorrhage may occur, in consequence of wound of the large arteries.

Treatment.—The same indications for treatment are present in these cases as have been alluded to in cases of penetrating wounds of other parts of the abdomen. Ex-

travasation, peritonitis, and death are practically certain to follow on them if perforation of the stomach wall has occurred, unless the usual means of closing the apertures and cleansing the cavity be employed. Hæmorrhage equally demands laparotomy. As soon, therefore, as a wound over the region of the stomach has been ascertained to penetrate the parietal peritoneum, no delay should be allowed before operative interference is undertaken, except the time necessary for the patient's recovery from the primary shock to such a degree as will enable him to bear it.

The median-line incision will, almost in all cases, be found to be the most convenient, as giving better access to the organ, and greater facility for the thorough cleansing and flushing out of the peritoneal cavity. Vessels requiring it should be ligatured, and the apertures in the stomach walls closed by Lembert sutures. When there is only one opening, and this in the anterior wall, the operation of suture is comparatively easy; but in gunshot cases simple penetration seldom occurs, while incised wounds and sword and bayonet thrusts are less often complicated by complete perforation of both walls. Suture of a wound of the posterior wall of the stomach may be done either through an incision in the gastro-colic omentum, or by enlarging the opening in front, and drawing the lips of the posterior wound forward through that in the anterior wall and sewing, on Maunsell's plan (see diagrams on p. 369), with horse-hair passed through all the coats of the viscus.

The removal of the extravasated contents of a wounded stomach from the cavity of the peritoneum, and the accurate cleansing and irrigation of the membrane, are more difficult, and the imperfect performance of this portion of the operation has, if possible, more fatal results than are observed in cases of wounds of any other part of the intestinal tract. If food has been taken a short time before the occurrence of the injury, large pieces of partly digested material may become scattered throughout the abdominal cavity; and in any case the contents of the stomach have a most irritating effect on the peritoneum, producing pro-

found shock and extreme pain. Fragments of food are liable to become lodged between the diaphragm and the liver, and to escape removal unless great care be exercised for this purpose. For these reasons especial attention must be paid to the removal of extravasated matter in these cases, and more particularly to the cleansing of the sub-phrenic spaces. Visible portions of food should be removed with pledgets of antiseptic wool wrung out of hot boracic lotion, the space between the upper surface of the liver and the diaphragm receiving special attention in this way. The outer surface of the omentum, over which the stomach contents are certain to flow, the flanks and the cavity of the pelvis, into which they are likely to descend, should be cleaned in the same manner. Then the whole peritoneal cavity should be thoroughly irrigated, in a full stream, with hot (105–110° F.) boracic lotion, while the hand is gently moved about amongst the intestines, to ensure complete flushing out of all irritating matter.

Some authors recommend the attachment of the stomach to the abdominal wall, at the site of the anterior wound, to ensure the outward escape of any leakage which may occur; but this should be unnecessary if sufficient attention be paid to the suturing. A much more important matter is to provide for the escape of discharges produced by extravasated matter which may have been left behind, and for this purpose Barker uses drains of iodoform gauze: "one strand reaching deeply between the liver and diaphragm on each side, another to the suture in the stomach, and a fourth down behind the gall-badder."[1] These drains are left in for five or six days.

The lines on which the feeding should be carried out in these cases have been already indicated at page 377.

Liver.—Gunshot wounds of the liver are much less frequent than wounds of the intestine, and more frequent than those of the stomach or any of the other solid organs in the abdomen. Bullets at short ranges produce most extensive lacerations of the "explosive effect" character, accompanied by such severe hæmorrhage that death usually occurs

[1] *Lancet*, 5th December 1896, p. 1587.

immediately (fig. 86). At long ranges the apertures made in the liver may be of less diameter than the bullet, and the damage to the organ may not be very great, unless some of the larger arterial or venous trunks are implicated. The position of the wound in the parietes and

FIG. 86.
Result of gunshot through liver at short range.—*Netley Museum.*

the direction of the track are the only grounds on which a diagnosis can be based, and should be sufficient for this purpose.

The Treatment should be directed to controlling the hæmorrhage, which is usually very free in these cases. This may be done when the wound is small, by suturing the capsule together over it, or in other cases by touching it lightly with a Paquelin's cautery, or by plugging the wound with a strip of aseptic gauze, the end of which is left in the external wound for the purpose of removal after forty-eight hours. To carry out any of these procedures

the external wound must be enlarged. Wounds of the larger hepatic vessels, if such cases should live long enough to reach the field hospital, can hardly be amenable to surgical treatment other than that above suggested. When the gall-bladder is implicated in the injury, the edges of the aperture should be stitched to the opening in the abdominal wall, and a drain put in. Cases in which the damage to the liver is not excessive, and in which the hæmorrhage can be controlled, should recover, but the usual death-rate is very high. A wide bandage, exerting firm pressure, should be used to fix the dressings. Wounds of the stomach, as well as those of the liver, may be further complicated by being accompanied by wounds implicating the pleural cavities.

There were 173 cases of gunshot of the liver in the American War, with a mortality of 63.5 per cent.; the diagnosis was not certain, however, in a large number of them.

Punctured and incised wounds of the liver are very rare in warfare. Otis only records three such cases in the American War, of which two recovered; but he remarks that the "accuracy of diagnosis may be questioned" in the latter.

The Spleen.—Wounds of the spleen are extremely grave injuries. Otis recorded 29 cases, of which 27 died, or a death-rate of 93 per cent. Hæmorrhage from the almost erectile tissue of the organ is the usual cause of death; it may occur either as a primary or as a secondary complication.

Without laparotomy, wound of the spleen can only be suspected from the position of the external aperture, as there are no symptoms from which a diagnosis can be formed, apart from those of severe internal hæmorrhage. The injury is likely to be complicated by wound of the stomach, intestines, or left kidney.

In the Treatment of these cases, if the hæmorrhage, after enlargement of the wound, cannot be controlled by the same direct means as have been recommended for bleeding from the liver, nothing remains but splenectomy,

an operation which has been shown to be more successful when performed for injury than for disease.

The Pancreas.—Cases in which the pancreas is injured, either by gunshots or stabbing weapons, are nearly always fatal, probably in consequence of the very severe lesions which must necessarily occur at the same time. The close relationship which exists between this organ and the stomach, duodenum, spleen, left kidney, and the large vessels of the abdomen, renders it certain that wounds of the pancreas will be accompanied by injury to other structures within the abdomen which are of an extremely fatal character. Otis speaks of five cases of gunshot of the pancreas with one recovery. Other authors record a few cases of wound of the pancreas with recovery, in which the diagnosis was beyond cavil, because hernia of a part of the organ occurred, and some of it was removed. There are no symptoms indicative of wound of the pancreas, but a doubtful diagnosis may be arrived at by judging from the position of the aperture and the line of the bullet track.

In the Treatment, the abdomen should be opened, and the lesions dealt with according to the general principles already laid down for the treatment of abdominal wounds. Lacerated and shreddy portions of the organ itself may be removed without causing death, as has been proved by the recovery of some cases in which herniated pieces were excised; but little is known of what the results of wounds of the pancreas might be expected to show as regards their mortality, because of the severity of the other injuries which must complicate them and mask their particular effects.

The Kidney.—Wounds of the kidney are not so necessarily fatal as one might expect. They are usually accompanied by injury to the peritoneum and other organs in the abdomen, and occasionally by fracture of the vertebræ; under these circumstances the prognosis is, of course, very grave. But when they are produced from behind, or laterally, and the peritoneum is not implicated, as may frequently occur in punctured and incised wounds, and exceptionally in cases of gunshot, they may not be very

fatal injuries, unless they are great in extent. The frequent causes of death are hæmorrhage and peritonitis.

The Symptoms of wound of the kidney are fairly definite and easy of recognition. A wound in the loin over the region of the kidney, or a bullet track leading in its direction, pain in the loin passing into the groin and thigh with retraction of the testicle, and hæmaturia, are the signs indicative of wound of the kidney.

When the wound in the gland has extended to the pelvis or tubular structure, extravasation of urine is certain to occur; and if the peritoneum be opened at the same time, urine will be effused into the abdomen, and will rapidly set up peritonitis. When the wound does not communicate with the peritoneal cavity, but the pelvis of the organ is wounded, extravasation into the cellular tissue will take place, giving rise to peri-renal suppuration and abscess in the loin, ending, if the patient survive, in urinary fistula, which usually closes eventually, but only after a long interval. The hæmaturia may vary from mere blood-stained urine to almost pure blood, and clots may form in the ureter and bladder, blocking the former and almost filling the latter. Wounds of the kidney in which the peritoneal cavity is opened, as is almost always the case in bullet injuries, are usually accompanied by lesions of other abdominal viscera, the spleen and descending colon on one side, and the liver and ascending colon on the other. Superficial wounds of the kidney, not opening the calyces or pelvis, do not give rise to urinary extravasation, and are of themselves not very dangerous. The mortality of all the 78 cases of wound of this organ recorded by Otis was 66.2 per cent.

Treatment.—When the wound implicates the abdominal cavity, laparotomy should be performed in order to explore the condition of the kidney, and to repair, if possible, the other lesions which may be assumed as certain to accompany it. If there be much destruction of the organ, and hæmorrhage, nothing remains but nephrectomy. If the wound be in the loin, it should be enlarged, for the complete exploration of the condition of the kidney, and to give free exit to the urine, and thus prevent its infiltration

into the lumbar muscles, peri-renal fat, and cellular tissues. A drainage tube should be used with these cases, and if hæmorrhage be going on, the wound should be firmly packed with strips of iodoform gauze with the tube in the centre. Retention of urine must be prevented, and any collections of pus which may form in the lumbar region should be attended to at the earliest moment. When blood-clots fill the bladder, it may be impossible to remove them without a perineal section, followed by breaking down the clots, and washing them out through a large tube, or a supra-pubic cystotomy might be substituted.

Searching for bullets and other foreign bodies lodged in the abdominal cavity or in the solid organs must be carried out with caution. If they can be discovered, they should, of course, be extracted if possible; but protracted attempts to find and remove them are not permissible, lest the damage be increased. Bullets lodged in the abdominal walls may become encysted and cause no inconvenience; if, on the other hand, they remain free in the abdominal cavity, and in the vicinity of a portion of intestine, they are likely to give rise to irritation and suppuration.

CHAPTER XII

INJURIES OF THE PELVIS

WOUNDS of the pelvis, as met with in war hospitals, are a distinctly less fatal class of injury than those of other portions of the abdomen. When the sigmoid flexure or rectum is wounded, recovery without operation, as has been already stated, is more likely to take place completely, or with a fæcal fistula, than is the case when the higher portions of the intestines are opened. This is probably due to the fact that drainage through the wounds is more likely to be free, and because, while extravasation is somewhat less certain in this situation, the peritonitis set up by escape of the bowel contents, when it does occur, is more likely to be circumscribed instead of diffuse. Nevertheless, the dangerous complications in these cases depend largely on the extravasation of the contents of hollow viscera. Hæmorrhage from the large vessels which traverse the pelvic walls is the other common cause of death from wounds in this region. Fractures of any portion of one or both innominate bones, as well as of the sacrum and coccyx, may also be found in gunshot cases; but these are not, *per se*, dangerous complications. Hæmorrhage, and extravasation of urine from wound of the bladder, are other common causes of death in gunshots of the pelvis; and when these occur, a fatal issue may be looked for if operative interference be not undertaken at an early period after the receipt of the injury.

The fractures of the pelvic bones which may be caused by large projectiles and fragments of shell are occasionally of an extremely destructive character, the whole ilium, or large pieces of it, being shattered, and driven in upon the contents of the pelvic cavity, which become so disorganised by the violence of the injury that life can only be sus-

tained for a few minutes. Fractures produced by small-arm bullets exhibit more of the characteristics usually seen in fractures of the ends of long bones, the structure of the pelvic bones being, like them, composed, for the most part, of cancellous tissue. Clean-cut, punched-out perforations without fissuring are found to be produced at long and medium ranges, while at short ranges fissures may extend from the shot holes for considerable distances. The surgical interest of the condition of the fracture of these bones consists in the liability to the occurrence of caries and necrosis, and the prolonged persistence of sinuses and suppuration if the wound become infected, together with the probability of the additional injury to the parts in the pelvic cavity from the action of bone fragments as secondary missiles.

The perforations made by bullets in the pelvic bones are in some respects similar to those seen in the bones of the skull: the surface on which the bullet makes its entrance is always more cleanly and evenly cut than that of the exit side, where the comminution is always greater.

The complications which, for the most part, render injuries to the pelvis dangerous to life, are the internal lesions which are so commonly associated with them—lacerations of the small intestines, bladder, sigmoid flexure, rectum, and of the large vessels of the pelvic cavity. Lesions of the small intestines have been already dealt with and need not now be referred to.

Wound of the Bladder is, next to wound of a large artery, the most fatal injury which can occur in these cases, especially when it implicates the peritoneal covering; but all perforations of this organ do not necessarily include wound of the serous membrane. When the bladder is sufficiently full to raise it into contact with the abdominal wall, it may be wounded above the pubes without interfering with the peritoneum; and again, when the missile or weapon perforates the pelvis from below, the peritoneum may escape; but it is opened in the majority of cases. When the wound is extra-peritoneal, the urine becomes extravasated into the areolar tissue about the neck of the

bladder, and between the peritoneum and the abdominal walls, causing, when it has had time to decompose, intense inflammation, suppuration, and sloughing of the parts. In intra-peritoneal wounds the urine passes into the cavity of the pelvis, rapidly producing severe peritonitis.

The Symptoms of wound of the bladder from gunshot are usually so clear as to leave no doubt as to the diagnosis. Shock and collapse are rapid in their onset and profound in degree, and, after an hour or two, the pain caused by the extravasated urine becomes intense. Urine may escape by the wound; a little bloody urine may be passed by the urethra or be drawn off by the catheter. Sometimes no urine passes by the catheter; or, on the other hand, if the point of the instrument happens to reach the rent in the bladder wall, a large quantity of bloody urine may be evacuated, not from the bladder itself, but from the pelvis, into which it has been extravasated. The patient has a constant desire to pass water, and strains to do so, but nothing passes, or only a few drops of bloody urine are got rid of. The presence of these symptoms, combined with the situation of the wound and the direction of the bullet track, are sufficient evidence of the nature of the case.

The Treatment of wound of the bladder is as clearly indicated as are the signs of the accident. In extra-peritoneal wounds the bladder must be freely drained to prevent further escape of urine into the tissues; and intra-peritoneal wounds require laparotomy for suture of the rent in the bladder wall, and for the perfect cleansing of the peritoneal cavity. When the bladder is torn, extravasation must continue until mechanical means are employed to close the opening, because the supply of the escaping fluid is inexhaustible as long as the patient lives, and the longer the process is allowed to go on, the more widespread and fatal must be its effects.

In cases of extra-peritoneal wound of the bladder the main object to be attained is to prevent any accumulation of urine within the organ, and this can be most efficiently carried out by providing free drainage through the urethra

or through the perineum. By this means all tension from urine within the bladder is obviated, and therefore the tendency to further extravasation is lessened or altogether removed. A large Jaques catheter should be passed into the bladder and tied in; if the wound be in a position suitable for drainage, the external opening may be enlarged if necessary, and a large tube inserted. If the drainage secured by these means does not appear to be effective, a median perineal section should be performed, and the usual gum-elastic lithotomy tube employed. Whatever method of drainage is adopted, the urine should be led, through a small rubber tube, into a vessel of antiseptic fluid placed beneath the bed. If the rent in the bladder, even though it be extra-peritoneal, can be reached and sutured, this should be done. Henry Morris[1] suggests that wounds produced in the front wall during a condition of distension of the bladder, are amenable to this latter method.

Intra-peritoneal wounds, while requiring almost as careful draining as the former cases, also necessitate the performance of laparotomy, for the purpose of repairing the internal lesion and flushing out the pelvic peritoneum, as otherwise death is absolutely certain to occur from septic peritonitis.

Sir William MacCormac[2] was probably the first surgeon in this country who successfully sutured the bladder for intra-peritoneal rupture. He has collected details of 16 cases in which the operation had been performed up to 1887, with 6 recoveries. Kerr, of Washington,[3] compiled a table of 29 cases in which laparotomy was performed for rupture or wound of the bladder, with 12 recoveries, or a mortality of 58.5 per cent.

As in the intestine, Lembert's is the method of suture to be employed. The stitches should be placed close together, and one or two should be inserted beyond the extent of the wound, so as to ensure a water-tight seam. The pelvic cavity and its contents should be thoroughly irrigated with well-boiled water, or boracic lotion, at a tem-

[1] "A System of Surgery," by F. Treves. [2] *Lancet*, 1886.
[3] Erichsen, *op. cit.*

perature between 105° and 110° F.; and the security of the seam may be tested by filling the bladder through a catheter in the urethra with warm boracic lotion, and if not perfect other stitches should be put in as required. If signs of peritonitis to any extent have been found in the pelvis, a glass drain may be used for twenty-four or forty-eight hours. A catheter may be tied in the bladder for the first three days; but this is not necessary if care be taken to keep the bladder empty and free of tension, by passing one every three or four hours.

The presence of symptoms of peritonitis cannot be considered as a contra-indication to this operation, as death is practically certain if it is not performed; but it, of course, greatly diminishes the chances of recovery.

Hæmorrhage from the walls of the bladder is sometimes very free; and if any of the vessels in the pelvis are wounded, it is certain to be so. This complication must be treated on the general principles applicable to such cases, it being remembered that the bleeding points can be reached only by laparotomy.

Modern small-arm bullets are not likely to lodge in the bladder; but during the American War, projectiles which had lodged and become encrusted with calculous matter were subsequently removed by cystotomy in thirteen cases. Other foreign bodies, such as pieces of the pelvic bones or fragments of clothing, are, if left in the bladder, certain to become the nuclei of vesical calculi, and to require operations for their extraction. Fragments of clothing are less likely to cause this complication than are the other substances mentioned, because the chances of their expulsion by the urethra are more favourable.

Wounds of the Rectum and Sigmoid Flexure are less dangerous injuries than those of any other portion of the alimentary canal, notwithstanding that they are so frequently complicated by wounds of the bladder and other contents of the pelvic cavity, as well as of its bony walls. In the American War 42.7 per cent. proved fatal. In the Franco-German War[1] the death-rate was 48.4 per cent. The com-

[1] Delorme.

paratively favourable conditions of these wounds are due to the facts that they may be extra-peritoneal in certain situations; that extravasation of their contents is less certain to occur, the fæcal matter being less fluid; and because in many cases the positions of the external aperture ensures more or less satisfactory drainage. The cases which recover without operation are usually followed by the formation of fæcal fistulæ.

The Diagnosis of these cases is not difficult: the appearance of fæces or intestinal gas at the wound, the passage of urine by the anus, or of fæcal matter by the urethra, the pain at the lower end of the bowel, and the direction of the bullet track are sufficiently strong indications to warrant a definite diagnosis and to justify an exploratory operation.

Treatment.—When the wound is from the front, and its position suggests the possibility of internal lesions—a condition which must exist in most cases—laparotomy should be performed early, and the usual steps taken for their repair and the irrigation of the peritoneum. In cases where the wound is in the perineum, or low down on the lateral or posterior aspects of the pelvis, it should be enlarged and free drainage provided for. The sphincters, which are usually tightly contracted from the reflex effect of the neighbouring injury, should be forcibly dilated or freely incised, to ensure easy exit of the bowel contents, and the rectum should be thoroughly washed out with antiseptic enemata. Iodoform emulsion in olive oil or vaseline should be frequently passed into the bowel by means of a small syringe or a rectal ointment introducer, in order to keep the part as aseptic as possible.

In some of the latter cases—wounds low down—where the bullet traverses the rectum above the reflexion of the peritoneum, suture of the intestine may be extremely difficult, or impossible, from the immobility of the gut, and the depth at which it is placed. Free drainage of the peritoneal cavity must then be supplied, and it is possible that inguinal colotomy might be of service.

Pelvic cellulitis and abscess in the tissues about the

rectum and anus are common sequelæ in these cases, and must be treated by incision, free drainage, and antiseptic irrigation.

Wounds of the Penis do not require any very detailed reference: they are, when due to gunshot, to be treated in accordance with the general principles of surgery. The orifices in the skin of the organ, and in the sheath of the erectile tissue, are usually of equal or less diameter than the bullet, whereas there may be considerable loss of substance in the track of the bullet through the corpora cavernosa. Gunshot wounds of this region are not of themselves very dangerous to life, but they are usually complicated by much graver injuries of the pelvis, hip-joints, and thighs. But, even when so complicated, 309 such cases in the American War only gave a mortality of 13.2 per cent. Traumatic stricture, when the urethra is implicated, and the primary hæmorrhage are the conditions likely to give trouble in the treatment of these cases. The dorsal vessel and the arteries of the corpora cavernosa, when severed by a bullet, do not usually give rise to severe hæmorrhage *per saltum;* but, on the other hand, the escape of blood from the cavernous bodies is often very free. But death by hæmorrhage from wounds of the penis is not very likely to happen, as is evident from the number of cases of Italian soldiers who survived mutilation at the hands of the Abyssinians in the late war, by the removal of the whole of the external genital organs.

Wound of the urethra is fairly easy of recognition; the situation of aperture and the direction of the bullet track, combined with the passage of blood by the urethra, or urine by the wound, and burning pain in the part during micturition, will be sufficient for a diagnosis of this condition.

The Treatment of wounds of the penis must be directed to stanching the hæmorrhage, closing the apertures in the skin by suture, and bringing the cut ends of the urethra together if it has been divided or opened.

Bleeding points, if any can be seen, should be ligatured, and pressure may be made by means of a gauze bandage, or, better still, by a strip of sticking-plaster,

over a large-sized gum-elastic catheter which has been passed into the bladder. If a hæmatoma has formed in the cavernous structure, it should be removed, and pressure applied as above suggested. If the urethra has been implicated, a catheter should be passed into the bladder and tied in, the cut ends of the tube being brought together by thin aseptic silk or gut sutures. The skin wounds should be closed by suture, and no difficulty need be anticipated in this procedure owing to the laxity of the tissues in this situation. A gauze and wool dressing should then be applied.

If it should be found impossible to pass a catheter in these latter cases, the distal end of the urethra must be found by cutting on a staff passed down to the wound, and the point of the catheter guided into the proximal end by means of a bent director or other similar instrument. In all cases of wound of the urethra, signs of extravasation of urine must be carefully watched for, and actively treated as early as possible.

The traumatic stricture which is so common a sequela of gunshot of the urethra is a very troublesome complication, and must be treated on the same principles which guide the surgeon in similar conditions due to other causes.

When the cavernous bodies are wounded, the resulting cicatrix is liable to give rise to distortion of the organ during erection.

Gunshots of the Scrotum and Testes give rise to hæmatocele, great swelling and inflammation of the loose tissues of the parts, and intense pain, accompanied by vomiting and signs of profound shock. Strict antiseptic measures and drainage are required in their treatment; the wounds should be thoroughly irrigated with an antiseptic solution, the hæmorrhage controlled, and a drainage tube put in. If one testicle has been badly damaged, it may be removed; but if both are injured, the remains of the organs should be preserved if possible.

CHAPTER XIII

THE EFFECTS OF THE USE OF MODERN SMALL-ARMS IN WARS OF THE FUTURE

THAT vast changes, from a merely surgical point of view, must take place in the conditions affecting the wounded in future wars, in consequence of the adoption of rifles of small calibre, is admitted by all who have had occasion to study the subject. The governments of all the civilised nations in the world have now armed their soldiers with rifles firing hard-mantled projectiles of from 0.322 in. to 0.263 in. in diameter. What will be the results of the use of these weapons in warfare? What will be the percentage of losses in future battles? What the ratio of killed to wounded? These are important questions; for on the data supplied by correct answers to them will depend the provision which the head of a medical department will have to recommend his government to make for the effective succour of the wounded on the field, and for their surgical treatment in the field hospitals.

Unfortunately—from one point of view—the evidence on these matters is at present defective in both quantity and quality. The Chilian War of 1891 was, as yet, the only campaign in which both sides were armed with modern weapons, and the reports relating to the subject under consideration are based on mere hearsay, and are therefore unreliable.

Regarding the probable effects of the new rifles in warfare, Billroth writes: "I am convinced that, in every form of fighting, the increased penetrative power and greater range of modern projectiles, and the use of smokeless powders, will, in the future, cause not only an increase in the numbers wounded, but also in the number of severely wounded men." Of the truth of the first part of this

statement, that in future wars there will be an increase in the number of wounded, there can be no doubt; but that the proportion of the severely wounded will be increased is a matter about which there is at present a great diversity of opinion, while there are comparatively few data on which to base an opinion which can carry weight.

An officer, whose position of command in the Chilian service during the war should entitle him to credence, stated that the proportion of killed to wounded was as 4 to 1; but this is contradicted by Captain von Heyking, of the German School of Musketry, who puts the proportion at just the reverse, 1 killed to 4 wounded, or about the ratio which has obtained in all other wars. In the late war between China and Japan, only one side, the Japanese, was partly armed with small-bore rifles; all other campaigns in which these weapons were used were conducted by a European army on one side and an uncivilised enemy on the other. Statistics which would indicate the ratio of killed to wounded are therefore not available, because in most cases nearly all the losses were on the enemy's side and were not accurately noted, and the losses on the European side were caused by obsolete weapons, and statistics, if compiled, would therefore be useless towards clearing up the matter here referred to.

Widely differing opinions are held regarding the severity of the wounds resulting from the new projectiles, some authorities considering the weapons discharging them as unsuitable for use in warfare on the ground that the injuries produced by them are trivial, and others, on the contrary, holding that they contravene the spirit, if not actually the letter, of the St. Petersburg Convention of 1868, because their effect within the body is in fact, if not in intention, an explosive one. The kind of injury produced by the modern small-arm bullet has already been described and need not be again discussed. But equally at variance are the forecasts which different authorities have made of the casualties which may be expected, in the next European war, to result from the use of modern rifles.

Tables showing the percentages of killed and wounded in the various battles of the last 100 years, such as those of Longmore and Fischer, tend to prove to the casual reader that the losses of the combatants from the use of small-arms have varied inversely as the perfection of the weapon employed, because the proportion of casualties in battle—with some occasional exceptions—are seen to have steadily decreased since rifles were invented and smooth-bores discarded; and, further, that as rifles have been improved in accuracy and range, so, apparently, has their destructive effect lessened. To refer to some of the figures from Longmore's table:[1] at Kunnersdorf, in 1759, the Prussians lost 20 per cent. and 38 per cent. respectively of killed and wounded; at Maida, in 1806 the French lost 53.3 per cent. of their army; at Albuera, in 1811, the British lost 13 per cent. killed and 40 per cent. wounded, 53 per cent. in all. At the Alma the total English loss was 9.3 per cent., and during the whole Crimean War our loss in killed and wounded amounted to 15.1 per cent. of the troops which landed on the peninsula. At Königgrätz, in 1866, the Prussian loss was 4.1 per cent., and at Weissenberg, in 1870, the total loss of the Germans was 1.4 per cent., while at Gravelotte it was 7.3 per cent., and at Sedan 4.7 per cent.; at Amiens, in 1870, the Germans lost 0.3 per cent. killed and 1.95 per cent. wounded, and at Le Mans, in 1871, there were 0.23 per cent. killed and 0.72 per cent. wounded. These figures are taken at random from Longmore's table—they are not selected with a view to upholding any particular contention—and they cover the periods from the time of smooth-bores to that of the Chassepôt and the Prussian needle-gun. Judging from them alone, one might be tempted to imagine that perfection in the weapon counted for nothing in producing the effect for which it is employed; that "Brown Bess" killed and wounded more of the enemy than do the modern rifles, and that the sooner we hark back to the latter fire-arm the better!

It may be true—indeed it certainly is true—that the

[1] *Op. cit.*, p. 700.

percentage of killed and wounded was greater in the Peninsular War than in the war of 1870–71; but it can hardly be seriously contended that the smooth-bore is therefore the more effective weapon. Yet statements of this kind have been made. The apparent contradiction may be open to other explanation; and that it is so, will, I believe, be evident on further consideration of the subject.

The compilation of the statistics of the losses—killed, wounded, and missing—incurred in battle is extremely difficult, and errors are likely to be committed in many ways. The reports are hurriedly made up, in order to get this anxiously expected news despatched at the earliest moment; amended returns sent in a day or two later may be mistaken for additional returns, and thus the casualties may become nearly doubled; and once an error has crept into statistics and is published, it is almost impossible to rectify it. Men who are merely "missing" get returned as "killed," and *vice versâ*, and when the mistakes are discovered they may not be corrected, or the correction may not be perceived. Men so slightly injured as not to have to leave their corps, but who remain at duty, go to swell the number of the "wounded." Moreover, the natural tendency of each side is to minimise their own losses and to exaggerate those of the enemy. In these and in many other ways errors arise.

But, when we come to consider statistics of the casualties of a particular battle in order to form an opinion of the effects of the arms employed by the combatants, the important matter to be informed upon is the data on which they are based. Are the percentages of losses calculated on the total strength of the army present? or are they based only on the strength of those actually *engaged and under fire?* If upon the former, any deductions drawn on this point must be erroneous. If, for instance, 10 per cent. of casualties occurred in an army of 50,000 men present on the field, only 25,000 of whom took active part in the fight and were exposed to injury, while the other 25,000 were in reserve and out of range, it would be absurd to put the casualties at 10 per cent.; they would be, in fact,

20 per cent. The 25,000 men who were not engaged might, no doubt, have been useful under other circumstances; but as events turned out they were not required, and, as far as affording means of judging of the effect of the enemy's fire is concerned, they might just as well have been one hundred miles away from the scene of action. At the battle of the Alma[1] two divisions of the English army were not engaged at all; and von Moltke states that 92,000 men of the Prussian army present at Königgrätz never fired a shot.[1] It is far easier to calculate the percentage of killed and wounded on the strength of an army *present* at a battle than it is to ascertain the strength of the troops *actually engaged* and to take the latter number as the basis of calculation, and this is the method by which the ratios are usually carried at. But statistics of this latter kind are misleading as evidence in comparing the lethal effect of one weapon with that of another; because, although 5 per cent. of the whole army may represent the losses occasioned by the rifle, yet half the number of men actually exposed to its fire may have been killed or wounded by its projectiles.

When armies are numerically small, the chances are that all the troops become engaged, and the proportion of casualties is then high; when, on the other hand, they are large, the probability is that not all, or nearly all, come under fire, and then the proportion of casualties is low if the ratios are calculated on the total strength. These considerations afford one explanation of the relatively small percentages of killed and wounded in the battles in modern times, for the armies present at them have been very large.

Referring again to Longmore's table: at the battle of Maida, in 1806, the French had an army of 7500 men, and lost in killed and wounded 53 per cent.; at Wagram, in 1809, the Austrian army was 90,000 strong, and lost 28 per cent., and the French, with 140,000 men, lost 22 per cent.; at Albuera the English numbered 7530, and lost 52 per cent.; at Leipsic, in 1813, the allied army contained

[1] Longmore.

300,000 men, of whom 16 per cent. were killed or wounded, while the French army was 171,000 strong and lost 36 per cent.; the German army of 119,000 men at Saarbrück, in 1870, lost only 4 per cent.; at Woerth, in 1870, 160,000 Germans lost 6.6 per cent., while 46,000 French lost 63.9 per cent. These cases are selected from the table as instances bearing out the view that small armies suffer a greater percentage of losses in battle than large ones, every man being brought up and exposed to fire, and the ratios of casualties being then correctly based on the total strength. But when the casualties are calculated on the total strength of an army, only part of which is exposed to fire, the proportion of killed and wounded appears to be less than it really is. Longmore's table does not show this in every case, but the general principle here referred to is, on the whole, borne out by it. Moreover, this is a more natural and common-sense view to take of the circumstances than it is to attribute the lower rates of casualties observed in modern battles to the increased accuracy and range of rifled small-arms, for these are the qualities in which the new weapons differ from the old, and this is the *reductio ad absurdum* which this argument entails—that because the range of the old "Brown Bess" was short, and the flight of its projectiles erratic, therefore its power of killing and wounding men was greater than that of the more perfect weapon!

The Proportion of Killed to Wounded in battle has varied largely in different campaigns, and depends to a considerable extent on the conditions under which actions are fought—the tactics employed by the commanders, for on these depend the distance maintained between the opposing forces; the nature of the ground, as to its affording cover, and thus exposing only the more vital parts, the head and chest, to injury; and whether or not the engagements in a campaign consist for the most part in attacking entrenched positions, where one side is exposed, at short ranges. In the Russo-Turkish War of 1877–78, where the latter conditions existed, the proportion of killed to wounded amongst the Russians was as high as 1 to 2.1. At

Blenheim, in 1704, it was 1 to 1.3, nearly as many killed as wounded; while at Borny and Vionville, in 1870, the proportion amongst the French was 1 to 7. But summing up the available statistics on this point shows that hitherto the proportion of killed to wounded has been, on an average, as 1 to 4.[1] This refers to the numbers found dead on the field; while of those who reached the hospitals alive a large proportion die during the first two or three days, but these are not included in the figures given above. During the Russo-Turkish war of 1877–78, 11.8 per cent. of the wounded under treatment died in the army of the Danube, and 13 per cent. in the army of the Caucasus.[2]

According to Fischer, whose statistics are probably the most accurate on this subject, the proportion of killed to wounded has in certain campaigns been as follows:—

At the battle of Kunnersdorf, 1759,	as 1 to 1.9
" " Leipsic, 1813 . .	" 1 " 2.0
English in the Crimea	" 1 " 4.4
French " " . . .	" 1 " 4.8
Prussians in Schleswig-Holstein, 1864	" 1 " 1.8
" at Königgrätz . .	" 1 " 3.6
Austrians "	" 1 " 3.0
Germans in 1870–71	" 1 " 5.4
Russians in 1877–78	" 1 " 2.1

or an average of 1 to 3.2. This proportion probably fairly well represents the relation between the numbers of killed and wounded in previous campaigns. What it will be in the next European war, where modern weapons will be used on both sides, we have no evidence to judge by, and an approximate opinion can only be formed from a knowledge of the characters of the injuries produced by hard projectiles of small diameter.

That the percentage of hits amongst those troops actually under fire will, in future, be greater than formerly, can hardly be doubted. How can it be otherwise when we consider that the weapons employed will discharge at

[1] Longmore.

[2] *Compte-rendu du Service de Santé Militaire pendant la Guerre de Turquie de* 1877–78, par N. Kosloff, 1887.

least ten times as many missiles in a given time as the older fire-arm discharged, that the reserve of ammunition on the field will usually be practically inexhaustible, and that the combatants will be under effective fire at such extreme ranges as 3500 yards? But the proportion of killed to wounded will depend upon the kind of injury caused by the new projectile. Its great energy will enable it to penetrate the skull at ranges of over 2200 yards, while the soft leaden bullets often failed to fracture the bones of the head at 900 yards or less; and the bony walls of the chest will not arrest its passage at even greater distances. In former times death on the field from primary hæmorrhage was not rare, when large vessels were lacerated; the modern bullet, we know, produced that kind of opening in a blood-vessel, large or small, which is least capable of becoming closed by nature's hæmostatic processes, and therefore death upon the field from this cause will be even more common.

For these reasons we are certainly justified in, at all events, suggesting a probability of a larger proportion of killed to wounded in future wars. Von Bardeleben believed that it will be so. The German Report, by von Coler, puts the case as follows: "The proportion of killed to wounded on the battle-field of the future may perhaps be said to depend upon the range at which the main combat is fought out; up to 600 yards the number of killed will not be far behind that of the wounded, while at over 1100 yards there will be many more of the latter." This is probably correct; but the whole subject is one of doubt and speculation, which nothing but future experience can determine.

The question of what **the total losses** will be in the next great war is another subject on which there are great differences of opinion: some authorities believing that they will be enormous; while others, again, can see no reason to expect any increase of casualties, or even suggest that they may be diminished in number as compared with those of former campaigns. Von Coler gives a table showing the percentages of casualties, killed and wounded, to the

strength of the armies in certain campaigns, in which they are shown to have varied from 17 per cent. amongst the Germans in 1870–71, to 68.4 per cent. in the American War; but some, at all events, of these are incorrect, being placed too high. In this connection Longmore's table[1] is probably the most trustworthy, being compiled from "impartial sources and official returns."

To give a general idea of the losses sustained in killed, wounded, and missing in previous battles up to and including the Franco-German War, the following extract of some of the figures in Sir Thomas Longmore's table is appended:—

Table Showing the Losses per cent. of Strength in Various Battles.

Battles and Dates.	Strength.	Total Losses Per Cent.
Blenheim, 1704 { British and Allies	56,000	23.0
Blenheim, 1704 { Gallo-Bavarians	60,000	66.0
Kunnersdorf, 1759, Prussians	40,000	65.0
Talavera, 1809, British	22,000	24.6
Vittoria, 1813 { British and Portuguese	60,486	7.6
Vittoria, 1813 { British alone	35,129	9.4
Leipsic, 1813 { Allies	300,000	16.0
Leipsic, 1813 { French	171,000	36.0
Waterloo, 1815, British	36,240	23.3
Alma, 1854 { English	21,481	9.3
Alma, 1854 { Russians	60,000	9.3
Inkerman, 1854 { English	14,000	20.1
Inkerman, 1854 { French	41,000	4.5
Inkerman, 1854 { Russians	55,000	28.6
Crimean War, English	97,864	15.1
Solferino, 1859 { French	135,234	12.7
Solferino, 1859 { Austrians	163,124	13.6
Gettysburg, 1863 { Unionists	117,350	19.7
Gettysburg, 1863 { Confederates	68,352	46.2
New Zealand War, 1863–66, British	7,930	8.6
Prusso-Danish War, 1864, Prussians	46,000	5.3
Weissenberg, 1870, Germans	106,928	1.4
Woerth, 1870 { Germans	167,119	6.3
Woerth, 1870 { French	46,000	36.9
Gravelotte, 1870 { Germans	278,131	7.3
Gravelotte, 1870 { French	125,000	8.0
Franco-German War, whole German army	887,876	13.2
Beaune-la-Rolande, 1870, Germans	91,405	0.95

The average of the above ratios amounts to about 16 per cent., while that of Longmore's complete table is

[1] *Op. cit.*, p. 700; 2nd edition, 1895.

about 17 per cent., of the total strengths *present* at the different engagements. The information contained in this table is of considerable historical interest, but it must be remembered that it affords no means of computing the probable losses in future wars. It comprises only the results of the use of smooth-bore weapons and of muzzle- and breech-loading rifles. But since the time of the last war included in it, small-arms have not only been greatly improved in accuracy and range, but their capability of fire has been increased fourfold by the addition of the magazine; machine guns discharging what may almost be termed continuous sheets of metal have come to be part of the ordinary equipment of regiments; and artillery fire has been enormously extended in rapidity and range by the invention of more perfect guns capable of quicker discharge, as well of shells which burst into more numerous fragments. What other effects can these changes have in future battles than to rise the percentage of casualties, notwithstanding that the tactics of the generals in command will be mainly directed to obviating the lethal results of the new arms.

The Work of the Bearer Company in the Field.—By how much the percentage of casualties will be increased no one can accurately foretell; it may be by 10 per cent. or even 20 per cent. But taking it at only 3 per cent. on the average of Longmore's table (17 per cent.), let us see how the present arrangements in European armies will work out as regards the succouring of the wounded on the battle-field and conveying them to the field hospitals.

This would give 20 per cent. of casualties on the strength of troops present; of these 5 per cent. would be killed outright, and 15 per cent. wounded. A division of an army, amounting in round numbers[1] to 10,000 men, would therefore have 1500 men wounded, of whom 500, or one-third, would be severely wounded, and would require to be carried off the field, and 1000 slightly wounded, most of whom might be able to walk to the collecting and dressing stations. This latter supposition takes a most sanguine view

[1] A division equals 10,072 officers and men.

of the condition of the slightly wounded; more probably at least half of them would require carriage. But taking it as above suggested, it will be found that the ideal work of the bearer companies—viz., that the wants of all the wounded should be attended to on the day of the battle, and the patients placed in the shelter of the field hospitals—cannot be performed.

For the carriage of the wounded to the collecting stations there are two bearer companies, forming 16 stretcher squads, attached to a division of an army; and, besides these, provision is made for regimental aid to the extent of 70 stretcher squads, or 86 stretchers in all. The 500 severely wounded must be carried to the collecting stations by the 86 stretcher squads, or, in other words, the bearers must make a little over five journeys each way. The amount of time and labour which will be expended on each journey will depend on the distance between the fighting line and the collecting stations in the rear. The position of a collecting station should be one which places it out of range, or out of the line of fire, and only under exceptionally propitious circumstances as to the formation of the ground can this, in future, be at a less distance than 2000 yards. The time, therefore, which will be required for loading and unloading the stretcher and making the double journey cannot be less than two hours, if so little. Thus the stretcher squads would be engaged in most laborious work for ten hours, and then would hardly have accomplished their task. No men, no matter how willing and well practised, could stand so severe a tax upon their strength and energies. The stretcher squads of the bearer companies are composed of four men each, which admits of reliefs of the bearers carrying the wounded man. Their work would be sufficiently difficult; but in how much worse a plight will be the squads forming the regimental aid, where the stretchers are carried by only two men each, and how much longer will be the time required for each journey.

From these considerations it will, I think, be evident that the work of collecting the wounded at the first post of

surgical assistance cannot, in future, be performed in European armies as at present laid down by regulation. And yet the case as taken above is one in which the circumstances are put in the most favourable light possible, for it makes no provision for the necessity for carriage of any of the slightly wounded men, and it is certain that large numbers of these would be unable to walk to the collecting stations.

Then, again, the transport of the wounded from the collecting stations to the dressing stations, and on to the field hospitals, would be performed by the twenty ambulance wagons of the two bearer companies, and each wagon is capable of carrying an average of nine men on each journey, some sitting and some lying down. All the severely wounded, and at least half of the slightly wounded cases would require transport in this case, or 1000 in all. Each wagon would therefore have fifty men to provide for, and to do this six double journeys would be necessary. During the Franco-German War the field hospitals were, on many occasions, posted as far as seven miles from the scene of action; but, putting the distance at four miles, each wagon would have to make six double journeys of four miles, or forty-eight miles in all, and the time occupied in carrying out this work could not be less than twenty-four hours—a task beyond the capabilities of either the wagon-teams or their drivers.

Even this is not all: another difficulty is certain to arise in connection with the transport of wounded men from the field, viz., that the seventy stretchers to be supplied and manned by the regiments and corps of divisions will not be available for disposal by the medical department. The business of the commander of an army is to win battles; the prospect of the wounded lying long on the battle-field may touch his heart, but it is unlikely—regulations notwithstanding—to so influence his head that he will permit the removal of 140 men from each division at the supreme moment when, with arms in their hands, they could assist in gaining what is, from his point of view, the primary object of their presence at the seat of war.

It will, I believe, be apparent, from this view of the circumstances under which the wounded can be collected and carried from the field, that the old methods of performing these duties are no longer suitable to the present conditions of warfare, and must be abandoned. The unattainable ideal must be given up, and what is the best possible under the existing circumstances must be substituted for it. It need not be expected in future warfare, as formerly, that all the wounded shall be carried to the field hospitals, and their wants attended to, on the day of a battle; it will be a physical impossibility. As many of them as may be must be so cared for, and more than this cannot be hoped for from a medical service. The rest of the wounded must take their chance; and in proportion as these others are numerous, so will the horrors and sufferings of war be increased.

But even if the bearer companies could be so increased in number that the man- and horse-power would be physically capable of performing the necessary work, the old ideal would still be impossible of attainment. It will be impossible for the bearer companies to work in the immediate rear of the fighting line, as under present regulations they are supposed to do; for if they attempt it in the face of projectiles from weapons which are effective at such ranges as are the modern arms, they will only add to the numbers of the killed and wounded, and the bearers themselves will then require to be carried to where they also can receive surgical treatment.

Mr. Archibald Forbes,[1] who has probably been present at more battles than any other man now living, writes on this subject: "In the Franco-German and Russo-Turkish Wars, I had already personally recognised, and had written in that sense in my war correspondence, that the losses among the bearers and surgeons were so great that the service (work in rear of the fight) already approached impracticability. And I added, with a prescience which stands justified to-day, that in the warfare of the future the service as now existing will be found utterly impracti-

[1] "Studies of War and Peace."

cable, since, with the improved man-killing appliances certain to be brought into action, the first battle would bodily wipe out the bearer organisation carried on under fire." Billroth and Bardeleben were of opinion, after their experiences in the Franco-German War, that it will be no longer possible to remove the wounded during the battle, as the bearers would be more exposed than the men of the fighting line; that the most that can be aimed at is that in future the wounded shall be attended to within twenty-four hours; and that the present system must be abandoned. No doubt, on some exceptional occasions it will be possible to attend to the wounded on the field, and to carry them to the collecting stations, during the battle; but this can only be when the formation of the ground is such as will afford sufficient cover to the officers and men of the bearer companies to very greatly reduce their chances of being added to the casualties, or when the scene of the fight has been so far advanced as to put them out of range, or its direction has so changed as to leave them out of the line of fire. Under other circumstances than those just mentioned, nothing can be done until the engagement is finished.

While admitting that this prospect is indeed disheartening, Mr. Forbes[1] considers that it possesses some features tending to mitigate its gloom; for he believes that "the enforced remaining on the field until the battle is over, and indeed for hours afterwards, will not produce consequences so calamitous to the wounded as may be, not unnaturally, apprehended by those who sit at home at ease." He is of opinion that the hustling which the severely wounded man undergoes by prompt removal while he is suffering from shock is not always for his benefit, and that "he may lie without serious detriment, often with actual advantage, where he falls, for even so long a time as twenty-four hours, if the weather is not bitter." Mr. Forbes relates one or two cases, in his own experience, where wounded men were still alive, though unattended to, for four or five days; but they are instances of extraordinary tenacity of

[1] *Op. cit.*, p. 253.

life, and few surgeons will be found to agree with him in this hopeful view. The sooner wounded men can be attended to by the administration of hot liquid food materials, and by surgical treatment for their injuries, the greater will be the prospect of survival. But if the only organisation capable of carrying out this assistance is to be swept away by the enemy's fire when it is attempted too early, then such delay as will prevent this disaster must be admitted as an unfortunate necessity.

Whether the bearer company works close in rear of the fighting line, as at present ordered, or waits until the battle is over to commence its duties of attending to and removing the wounded, the system under which the work is performed will be the same, except that in the latter case the positions for the collecting and dressing stations may be so chosen as to place both as near as possible to the wounded, and thus lessen the labours of the stretcher bearers as far as may be feasible, and that, if there be a good water supply, the two posts may be combined. Absence of water would be the only necessity for separating the dressing station from the collecting station if the battle were finished, or proceeding at a distant part of the field; but this may be overcome by the use of the water-cart, which forms part of the equipment of every bearer company.

The Collecting Station is to be formed as near to where the wounded lie as possible, but out of fire or under efficient cover. The ten wagons of the bearer company are assembled and drawn up, ready to receive the wounded for transport to the dressing stations, and then on to the field hospitals. The two stretcher sections of four squads each, under the command of the third medical officer, go to the front, and having applied such surgical treatment as may be considered necessary, pick up the wounded and carry them to the collecting station, for transport to the rear. At this part of the field no operative procedures should be attempted, except the ligature of bleeding vessels; but even for this, opportunity will seldom arise, for hæmorrhage from vessels requiring ligature for its control will

usually prove fatal before assistance can arrive. Fractures of long bones should be provisionally put up by means of extemporary splints, such as swords, bayonets, scabbards, rifles, sticks, or straw gathered from the field, &c., &c., so as to prevent increase of the injury during transport. External wounds should be covered with first field dressings, without being wiped or "cleaned" in any way, or touched by hands or instruments. If more than this be done at the front, infection is sure to occur, and aseptic or antiseptic surgery will be rendered impossible or more difficult at the posts further to the rear; the men of the stretcher squads should be carefully instructed to this effect. More clothing than is absolutely necessary should not be removed from the patients, and when it is found unavoidable to open up clothing, this should be done at the seams; in this way articles of clothing will be less often lost, and repairs can be more readily effected. Each stretcher squad is supplied with a surgical haversack, which, with the surgeon's pocket-case, contains instruments and materials sufficient for all the necessary surgical work at the immediate front.

The Dressing Station.—The positions for the dressing and collecting stations having been selected, at the former, which is in the charge of a surgeon-major, assisted by a surgeon-captain or lieutenant, the operating tent is pitched if no suitable building be available. The dressing station should be placed near a good water supply if possible, and a road, passable by the bearer company transport, wheeled or pack-mule as the case may be, should connect it with the collecting station in front and the field hospitals in the rear. The surgical equipment should be unpacked and got ready for use. Water should be boiled, and an ample supply of this kept up during the performance of the surgical work. Nourishment and stimulants should be prepared for immediate use with the wounded as they arrive, and for this purpose a cook forms part of the personnel at the dressing station. If a severe engagement is taking place, extra medical officers should be lent to the dressing station from the regiments and field hospitals, as two will

prove quite inadequate to cope with the amount of surgical work which will be required.

The work at the dressing station will depend largely on whether or not the field hospitals are in their proper places. If they are close at hand and ready for the reception of patients, the difficulties of the medical officers will be considerably reduced; but if not, all the surgical work of the battle must be done, so far as may be possible, at the dressing stations. But in any case a considerable number of primary operations must be undertaken — amputations, excisions, ligature of arteries, &c.; and the equipment should be such, and the supply of surgical materials so complete, that thoroughly satisfactory antiseptic surgery may be quite feasible at these places, and this should always be aimed at. Stimulants, if required, and nourishment of the kinds already indicated in an early chapter, should be supplied to the patients immediately on arrival at the dressing station, and the usual means taken to recover them from the more or less profound constitutional shock which is usually present. The provisional treatment which has been applied in the field to fractures should be looked to, and, if necessary, steps should be taken to render it so secure that further damage cannot occur during transport to the field hospitals. As the patients are dressed they should be placed in the wagons, which, as they are filled, should be despatched to the field hospitals, in charge of the corporal and wagon orderly.

The principal medical officer of the division is supposed to arrange for the disposition of the bearer companies attached to it; but, in the absence of specific orders from him, the medical officers in command must of their own initiative make the arrangements which they may consider most desirable. The general idea of the working of bearer companies and field hospitals is laid down by regulation; but rules must be made to give way to circumstances, and the regulations cannot be too rigidly adhered to when other methods of arrangement and distribution seem likely to produce better results.

The Field Hospitals.—There are three field hospitals to

each division of an army, and thirteen to an army corps and cavalry division of 41,787 officers and men. They are lightly equipped, movable hospitals, intended only for the temporary treatment of 100 patients each, and are supplied with wheeled or pack transport according to the requirements of the campaign; they are divisible into half hospitals of fifty beds each, when this may be considered necessary. This will afford hospital accommodation for a little over 3 per cent. of wounded of the total strength of the army corps and cavalry division.

Field hospitals are non-dieted hospitals, the field rations, cooked as the medical officers may direct, and supplemented by such extras and medical comforts as they may order, being used in them. The bedding consists of a waterproof sheet and a blanket for each patient. No bedsteads are supplied; but if the hospital is to be long in occupation, every effort should be made to extemporise some means of raising the patients off the ground.

The site for a field hospital should be selected with a view to a good water supply and a road suitable for the bearer company's transport. If suitable buildings be available, they should be made use of; but if not, the tents should be pitched. The field hospital should be placed as near to the dressing station as possible, so as to shorten the journeys of the ambulances.

During the active operations of the troops a constant stream of convoys of sick and wounded should be kept up towards the stationary hospitals on the lines of communication and the base. When an engagement is imminent, the field hospitals should be emptied, so as to be ready to move forwards and receive the wounded from the battle-field; and when this is impracticable in the case of any particular hospital, in consequence of the class of patients occupying it, it must be left behind to come under the authority of the P. M. O. of the lines of communication, and an empty hospital advanced to take its place.

The press of work at a field hospital during, and for the first forty-eight hours after, a battle, is usually very great. Large numbers of wounded men requiring immediate

attention arrive almost simultaneously. Energetic means must be employed with most of these patients to combat shock and bring on reaction; food must be given to them; numerous primary operations must be performed; wounds must be washed, rendered aseptic, and dressed; fractures got into position and fixed—in a word, all the surgical necessities of perhaps 100 men, some of them slightly and some of them terribly injured, will require instant consideration and treatment. And this work has to be done by four surgeons, assisted by some non-commissioned officers and fourteen ward orderlies, unless outside aid can be obtained.

The slighter cases which have had first field dressings applied at the front may safely be set aside for treatment when the immediate press of work is over. Cases in which hæmorrhage appears to be going on should be taken first, because their needs are, for the moment, the most urgent if death is to be prevented; then the cases requiring operations should be attended to, and, perhaps lastly, those requiring the application of retaining apparatus for fractures of long bones. Cases which may not have had their wounds covered by first field dressings should have pads of gauze wrung out of an antiseptic lotion laid over the apertures, until such time as their treatment can be undertaken in greater detail.

Under the circumstances here presupposed—viz., the rapid filling of a field hospital with wounded—it must, unfortunately, happen that some limbs may have to be sacrificed by amputation which, in times of less urgent necessity, might be preserved. Saving of life is the first object to be aimed at; and it cannot be denied that primary amputation, when sufficient time cannot be devoted to the more scientific conservative treatment, may sometimes be able to effect the greatest good to the greatest number, by preventing death, even though it be at the expense of the loss of limbs which, under more favourable conditions, might have partially or wholly recovered their functions. I must admit the truth of this statement, strong upholder of conservative treatment and firm believer in Listerism as I am;

but in every case where the conditions favour it, the latter method should be employed. Any surgeon can amputate a limb—it is even on record that a sea-captain performed the operation when no more skilled person was available—but scientific surgery would be better exemplified by preserving it. Nevertheless, even conservative surgery must, on occasions, give way to the pressure of adverse circumstances when these cannot be overcome.

The hospitals on the lines of communication are more stationary and better equipped establishments than those just described. They are intended for the accommodation of 200 men each, and patients can be treated in them until such time as all risk of injury from transport has ceased. But the work carried on in these stationary field hospitals, as well as that in the general hospitals at the base, is in no way special or peculiar, and therefore requires no special description.

Sick and wounded men arriving at the base of operations are treated in the general hospitals there, until they are sufficiently recovered to be discharged to the military depôts attached to them, whence they are sent to rejoin their corps at the front as opportunity arises; or, if incapacitated from taking any further part in the campaign, they are invalided to England for disposal as permanently unfit for service, or for further treatment.

CHAPTER XIV

THE GENEVA CONVENTION

THIS is the title of a treaty entered into by almost all the civilised countries in the world, for the purpose of, as far as possible, lessening the sufferings of the sick and wounded in war. Its initiation is mainly due to the effect produced by the publication of a pamphlet written by a Swiss gentleman, M. Henri Dunant, in which he described what he saw of the unnecessary sufferings of the wounded after the battle of Solferino, in June 1859. At this engagement the number of the wounded on both sides amounted to over 22,000 in all, and the late Baron Larrey and the French surgeons found themselves quite unable to deal with such a mass of injured men, the result being that the immense majority of them had to remain for days upon the field without nursing or attendance of any kind.

M. Dunant described in vivid colours how terrible had been the experience of the wounded on the field at Solferino; he pointed out that, excellent as had been the medical arrangements made by Baron Larrey, no medical service could have been expected to provide sufficiently quickly for so many wounded men; and he then put forward his arguments in favour of supplementing the military medical services in all armies by volunteer aid societies. He especially indicated the need for outside assistance on the battle-field and in its neighbourhood during the first few days, or even weeks, after a battle. This was the suggestion from which the Geneva Convention, in its present very different form, originated—that the military medical services of armies on a campaign should be assisted in their duties by civil societies willing to provide surgeons, nurses, and equipment for this purpose.

The "Society of Public Utility," then existing at Geneva, took the matter up, and appointed a Committee with General Dufour as its president, for the purpose of encouraging and supporting the publication of M. Dunant's proposals, and the action of this Committee afterwards led to the meeting of the International Congress of 1863. This Congress assembled at Geneva and made certain recommendations, some of which were afterwards adopted, and some rejected; but the two principal results which followed on its report were the formation of National Committees in various countries for the purpose of considering how best to carry out M. Dunant's ideas, and the assembling of the International Congress of 1864 at Geneva, from which the present Geneva Convention emanated.

Geneva was selected as the place of meeting, because it was felt that Switzerland, having at that time no standing army of her own, and being therefore unbiassed, as it were, might initiate such a movement with greater propriety than could any other country.

Invitations to send delegates were accepted by sixteen of the European powers, and the Congress opened on 8th August 1864, at the Hôtel de Ville, Geneva. Twenty-five representatives, consisting of members of the diplomatic corps and of the military medical services of the different armies of Europe, met, and discussed the articles of the Treaty, and the Geneva Convention was signed on 22nd August 1864. The representatives of England on this occasion were the late Sir Thomas Longmore and General Brackenbury.

The special aim of the Convention was to obtain the neutralisation of the sick and wounded of belligerent armies, as well as that of the personnel and matériel necessary for the care and treatment of such sick and wounded soldiers in time of war. Hitherto all such persons, all hospital and ambulance transport, equipment, and stores, were looked upon as prize of war if they fell into the hands of the enemy. Under the Convention the sick and wounded, their medical officers, attendants, hospitals, equipment, stores, transport, and everything connected with their

lodging, feeding, movement, and treatment, were to be made free of interference at the hands of an enemy.

The Congress declined to consider the question brought up at the Congress of 1863 of independent volunteer aid societies being placed under the Convention, but carefully confined its privileges to the military medical services of the armies engaged. Many of the delegates stated that they had definite orders from their respective governments to withdraw from the Congress if the question of medical assistance, independent of the military services, were entertained at it.

There is no allusion to volunteers, red-cross societies, or medical aid societies in the articles of the Convention. There is indeed ample room and requirement for volunteer corps of medical attendants in a country at war; but should their services with the army in the field be accepted, it can only be on the condition that they become, for the time, part of the military establishment, and fall under the same military rules. They will then participate in the benefits of the Treaty, because they will be included in the field hospital personnel, and be amenable to military law in the same degree as is the rest of the army.

The articles of the Convention are nine in number, and are, briefly, as follows:—

No. 1. All military ambulances and hospitals shall be considered as neutral, and, as such, protected and respected by belligerents.

No. 2. All persons employed in attendance on, or in transport of, the sick and wounded, or of military hospitals, to be neutral so long as any wounded remain to be brought in or attended on.

No. 3. Even though the ground occupied by the above may be captured by the enemy, yet they may continue their attendance on the sick, or they may withdraw to join the corps to which they belong.

No. 4. The equipment of fixed hospitals remains subject to capture as prize of war; but that of field and movable hospitals is to be considered neutral.

No. 5. The inhabitants of the country who may bring

help to wounded men shall be respected, and shall remain free from capture or interference. A wounded man being taken care of in a house shall be considered a protection thereto.

No. 6. Wounded or sick solders shall be taken care of irrespective of which nation they may belong to. Commanders-in-chief may, if possible, and agreed to by both sides, hand over sick and wounded soldiers of either side to their own people. Recovered sick and wounded who are incapable of serving may be sent to their own country; others may be sent home on condition of not serving again in the campaign.

No. 7. A distinctive and uniform flag shall be used by all hospitals. An arm badge (brassard) shall be worn by neutralised individuals; but its delivery shall be left to the military authorities. The flag and brassard shall be a red cross on a white ground.

No. 8. The details of carrying out the Convention shall be regulated by the commanders-in-chief of the belligerent armies.

No. 9. The contracting powers shall communicate with those governments who did not send delegates, inviting them to join the Convention.

Five additional articles were agreed to in October 1868, amplifying, but in no way departing from, the spirit of the original basis of the Convention.

The desire to forward the object to be attained by the provision of hospitals, attendants, equipment, and matériel for the use of the sick and wounded in war — viz., the diminuton of the sufferings of the victims of campaigns — took very firm hold of the minds of charitably disposed persons, and national and private aid societies were formed in almost all countries for these purposes. But it soon became evident that quite erroneous ideas of the working of the Convention itself were entertained; and even now, although to a lesser extent, they are still held by persons who should be better informed. It was thought that any one who had the inclination and the means might join one or other side in a campaign for the purpose of succour-

ing the wounded, and that while so engaged he would be protected by the articles of the Geneva Convention. This misapprehension occurred from not studying the Treaty carefully. Private persons, no matter how praiseworthy and valuable their work may be, and aid societies, as such, acting during a campaign, have no recognised position under the Geneva Convention, unless this has been conferred upon them by competent authority. The privileges of the Convention, neutrality and inviolability of person, are not extended to them by the articles of the Treaty. On the contrary, persons undertaking these duties without the warrant and permission of the commander-in-chief are expressly excluded from its benefits. The Treaty only comprehends the military ambulances and hospitals of the belligerents, the staffs employed in attending on the sick and wounded contained in them, the transport used in moving them, the matériel and equipment required for the treatment of the sick, and the sick themselves.

No doubt private help, and the assistance of national and other aid societies, will be thankfully accepted, in the majority of cases, by foreign governments and commanders of armies in the field; but this can only be when the persons offering it come with proper credentials—*i.e.* the permission of their government, if assisting a foreign country—and on the condition that they shall, for the time being, form part of the military medical service of the army they become attached to, and be subject to the ordinary rules and articles of war, and then only by the authority of the commander-in-chief. This was so arranged because it was clearly foreseen by the contracting governments that to extend the privileges of the Convention to the members of irresponsible civilian societies would certainly lead to many difficulties. The possibility of spies carrying on their work under cover of the Geneva Cross is alone sufficient to condemn such a practice. The Geneva Convention is simply a treaty entered into by certain governments with regard to the manner in which the sick and wounded of their armies, and their military medical estab-

lishments and personnel, shall be dealt with in the event of war occurring between any of them.

Efforts have been made from time to time to induce the governments who signed the Treaty to include private aid societies and persons of this kind under its protection, but without any prospect of success; and until this is done they can only enter upon the theatre of war as private individuals, with no claim to exemption from the usual rules imposed in time of war, unless their assistance is accepted under the conditions and in the way already mentioned. Governments and commanders-in-chief will be only too willing to receive such help for their wounded soldiers, but they naturally insist that it shall be given only under such conditions as they themselves determine, and in accordance with the articles of the Convention.

The object I have had in view in making this short summary of the history of the Geneva Convention is to afford those desirous of such information an opportunity of forming correct opinions on a subject about which very erroneous ideas have prevailed, even amongst army medical officers, and because it is a matter of especial interest to members of the three medical services.

The notion is far too common that the Red Cross is a civil distinction, that it is a sign which may be carried by private individuals and by members of non-military societies, indicating that they are qualified and willing to aid sick and wounded persons, and the uses to which it has been, and unfortunately is being put, foster this misapprehension. Civil nurses wear it; it is placed on the labels of bottles of quack medicines, on the covers of surgical dressings, on all manner of things connected and unconnected with medicine and surgery, and certainly quite apart from military medicine and surgery.

All this is wrong. Persons who in this way mark themseves or their goods with the Red Cross make use of a sign to which they have no right or title, and they do it in absolute ignorance of the meaning of their own actions. The Red Cross is as purely a military distinctive mark as is any regimental badge worn as a part of a soldier's uni-

form. The people who now misuse the sign of the Geneva Convention might just as well, and with as little propriety, have adopted "the grenade" of the Grenadier Guards or the "harp and crown" of the 8th Hussars. These are both military badges; so also is the Red Cross a military badge, though it is one more universally used. It is the badge agreed upon amongst civilised governments whereby certain establishments in their armies, who shall not be subjcet to capture or interference in the performance of their duties during a campaign, shall be recognised.

Another point in connection with the working of the Convention about which misstatements have been made is the eligibility of a combatant corps, such as the Army Service Corps, to wear the brassard and be entitled to the benefits of the Treaty when performing transport duties for the medical establishments. It has frequently been suggested that, as the Army Service Corps may one day be employed in moving stores, guns, ammunition, or other articles strictly connected with the fighting capabilities of an army, and on another in the movement of field hospitals and bearer companies, it will not be protected by the Convention during the performance of the latter duties; that, in fact, a combatant corps cannot claim exemption under it even when performing strictly medical services, because such employment is but a temporary one.

This question was definitely settled in 1894. In July of that year I stated the case just referred to in a letter to the late Sir Thomas Longmore, which he forwarded to the President of "The International Committee of the Red Cross" at Geneva. M. G. Moynier, the President, assembled the Committee for the discussion of the subject, and its decision is now before me in M. Moynier's letter, dated 3rd August 1894, from which the following extract is taken: "It seems, then, to us without doubt, although the articles do not expressly say so, that if combatants are employed in the transport of the wounded, or in any other hospital work, *for all the duration of the campaign*, as is the case, it appears, for the men of the Army Service Corps, they can legitimately carry the international brassard, and

participate in the immunity it confers while they carry out this duty. This way of reading the second article of the Convention is in agreement with the intentions of its framers and with the spirit of the Treaty. But it is none the less certain that the use of the brassard under such circumstances should be associated with certain guarantees for the purpose of preventing the possibility of its abuse, which the enemy will be likely to suspect. The persons who fulfil at one time the duties of combatants, and at another those of medical aids, should especially be prevented from lightly discarding the brassard either from caprice or for their own interest. It would be wrong, for example, to put the brassard at their disposal previous to the time when the superior authority himself had given them to the medical establishments, or to leave them still in possession of this sign when they had ceased their medical duties. The authorities should therefore exercise the greatest vigilance with regard to this class of soldiers."

The phrase in italics in the above quotation — "for all the duration of the campaign" — might appear to leave the question still somewhat in doubt. But the case put to the Committee was—Would men who at one time are employed at combatant duties; and at another time in the transport of the sick and wounded, be entitled to wear the brassard under the articles of the Convention when acting in the latter capacity? and to this the answer of the International Committee was distinctly in the affirmative; and, moreover, the reference in the latter part of the Committee's reply to "persons who fulfil at one time the duties of combatants, and at another those of medical aids," shows the answer to be quite explicit, and that the Committee was alive to the exact point referred to it.

In future wars between civilised nations, where the armies engaged will be enormous, and the numbers of wounded probably far greater than on any previous occasion, the help of civil aid societies for the wounded must be accepted, but only with the conditions and restrictions already mentioned. No miltary medical service unassisted can, in future, efficiently carry out the work required of it,

and in almost every country in Europe that outside assistance has been so thoroughly organised and prepared that it is ready at a moment's notice when war breaks out. In England alone has this preparation been neglected. Here literally nothing has been done in the way of organisation so as to take the best advantage of the help, in time of need, of the civil aid societies, not because these necessary societies do not exist, and not because organisation has not been strenuously advocated, but for some other almost unaccountable reason. Two bodies exist in England, the St. John Ambulance Association and the British National Aid Society, which contain within themselves all that is requisite for efficiently supplementing the army medical service, should their assistance unfortunately be required; and the organisation which is necessary to bring these two civil societies into sufficiently close touch with the military service to ensure effective working of the two combined, has been persistently advocated for the last twenty-five years by Mr. John Furley, the greatest living authority on the subject in this or any other country.

Mr. Furley thoroughly understands the objects of the Geneva Convention and the means whereby these objects may be best attained; he is equally well acquainted with the civil aid societies, for he has spent his life in forming them; and he has had practical experience of both in at least three wars. He has made speeches and written papers without number, pointing out the lines on which organisation should proceed to enable the civil societies to amalgamate with the army medical service in time of need and give that assistance which everybody knows will be required in a great war, but only with the result already mentioned.

Mr. Furley's last effort in this direction was a paper read before the Royal United Service Institution on 24th April 1896, and printed in the journal for October of that year. It concludes as follows:—"Briefly summed up, our aim should be—

"(*a*) A more general appreciation of the Convention of Geneva, which was signed and adopted by this country

more than a quarter of a century ago, then pigeon-holed in the Foreign Office, and which has since remained almost a dead letter.

"(*b*) The recognition of the Red Cross as a military badge of neutrality, the abuse of which in time of war inevitably entails certain serious penalties, and which, therefore, in time of peace should be carefully protected.

"(*c*) The organisation of a powerful Red Cross Society, to be formed from the institutions already indicated, acting within their present limits in time of peace, but entirely under military control for all war purposes."

This is the kind of organisation for the adoption of which France and Italy, of Continental powers, have been especially praiseworthy, and these are the measures which will tend to prevent a repetition of the horrors, in suffering and death, which M. Dunant so ably described after the battle of Solferino.

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THE END